UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

SEDIMENTARY PROCESSES AND DISTRIBUTION OF PARTICULATE GOLD IN NORTHERN BERING SEA

By

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This report is preliminary
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<u>Explanation for caption</u>

Construction of expected curves is based upon Poisson (bionomial) distribution in manner similar to that used by Griffiths (1960). Expected number of gold particles, which is the parameter θ in the table B (p. 455-459) of the Poisson distribution given by Johnson and Leone (1964) or the parameter λ of table A-15 given by Dixon and Massey (1957), were calculated using the following modification of the equation of Moore and Silver (1968, p. 2):

$$\lambda = \frac{n\,\delta^{-1}}{0.314\,D^3 \rho \times 10^{-9}}$$

λ = expected number of particles

ρ = density of placer gold, 17 g/cc.

n = sample weight in grams. Values of λ were calculated for three sample weights, corresponding to the average of the smallest, intermediate, and largest one-third of the samples.

δ = tenor of deposit, in this case assumed to be 920 ppb; the average of all samples obtained.

D = diameter in cm. of gold flakes with a 10:1 diameter: thickness ratio. In this case, the effective diameter of gold particles was calculated using the equation of Clifton, et al. (1969, p. 15).

An expected curve was calculated using the values of λ obtained for each of six sample weight groups: the smallest, intermediate, and largest thirds of the individual samples, and the smallest, intermediate, and largest thirds of the moving-average samples. The final expected curves for each three sample weight groups of the actual samples and of the moving average samples were averaged to approximate the expected curve for a group of samples of varying weight.

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SEDIMENTARY PROCESSES AND DISTRIBUTION OF PARTICULATE GOLD IN NORTHERN BERING SEA

Hans Nelson and D. M. Hopkins

Abstract

Except for nearshore regions, most of northern Bering Sea is remote from bedrock sources of gold onshore and insulated by Tertiary sediments from possible bedrock sources below the sea floor. However, land mapping, and study of seismic profiles, 51 offshore drill holes, and 700 surface sediment samples show that during times of lowered sea level, glaciers have pushed auriferous debris up to 5 km beyond the present shoreline of Seward Peninsula and as much as 100 km off Siberia. Sediment textures, gold content, and presence of washed gravels far from the present shoreline indicate that subsequent transgression and regression of the sea has reworked the exposed margins of the glacial drift and left relict gravel as a thin lag layer overlying the glacial deposits; this veneer is richly auriferous along parts of the southern Seward Peninsula coast. During transgression and regressions of the shoreline still stands developed beaches at about -36' and -70' and -80' in the Nome region. Small amounts of gold are found in surface samples of the beach gravel, and better concentrations may be present at depth. Streams have dissected the offshore moraines during periods of lowered sea levels, and gold concentrations are present locally in the resulting alluvium, but the

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 (p. 1a follows)

gold concentrations generally are buried and have not been well sampled by the few scattered drill holes. Since the last rise in sea level strong nearshore currents have deposited sand, silt, and clay generally lacking gold, in the former stream valleys and in other topographic depressions; currents also have prevented the burial of auriferous relict gravel in nearshore regions of elevated topography and in offshore Chirikov Basin west of the Nome region.

Gold flakes one mm or more in diameter are responsible for high gold values in relict gravel; [redacted] the distribution of this coarse gold, as well as highest median values of panable particulate gold in local areas, provide evidence of the location of offshore gold sources. Gold flakes having diameters of one mm or more are essentially restricted to (1) areas in the vicinity of bedrock exposures on the seafloor, (2) areas near outcrops of mineralized material on land, and (3) areas where glaciers have carried *detrital material* en masse beyond the present shoreline. Small gold particles (ca. .25 mm or less) have been widely dispersed from these source areas by waves and bottom currents, but marine processes have not moved gold particles larger than 1 mm away from the source regions.

The fine-grained bottom sediments of northern Bering Sea contain small quantities of fine gold. Regional median values of pannable particulate gold amount to a few tenths of a part per billion in most areas in the Chirikov Basin, but gold too fine to be recovered in a gold pan is also present in small quantities. Regional median gold values are higher near source areas.

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 (p. 1b follows)

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Statistical tests on gold values of samples from a restricted area of relict surface gravels over drift in the Nome region suggest that coarse gold flakes (more than one mm) are randomly distributed, that average tenor is 920 ppb, and that a potentially mineable reserve exists. Geologic setting, and distribution of coarse gold particles indicates that the most likely locations of other auriferous gravel deposits in northern Bering Sea are (1) in relict surface gravel on older buried auriferous drifts off Nome; (2) in basal gravel of ancient stream valleys and beaches cutting drift off Nome; (3) at the sea floor in gravels over exposed bedrock near Sledge Island, and (4) on sea-floor exposures of moraines in northwestern Chirikov Basin, if they are auriferous. In general, offshore relict gravels deposited by shoreline or streams processes that rework glacial drift or bedrock sources with coarse gold, should contain significant concentrations of gold.

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9.1287

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INTRODUCTION

This circular reports methods of study and preliminary results of an investigation of the gold content in bottom sediments recovered in northern Bering Sea during the summers of 1967 and 1968. The study is concerned with the Chirikov Basin which is the part of Bering Sea bounded by the Seward Peninsula, the Yukon Delta, St. Lawrence Island, and the coast of the Chukotka Peninsula, Siberia (Fig. 1).

Figure 1 near here

Our results indicate that gold is widely dispersed on the floor of the Chirikov Basin and that several nearshore areas and a few off-shore areas merit further scrutiny in the search for gold placers of economic grade.

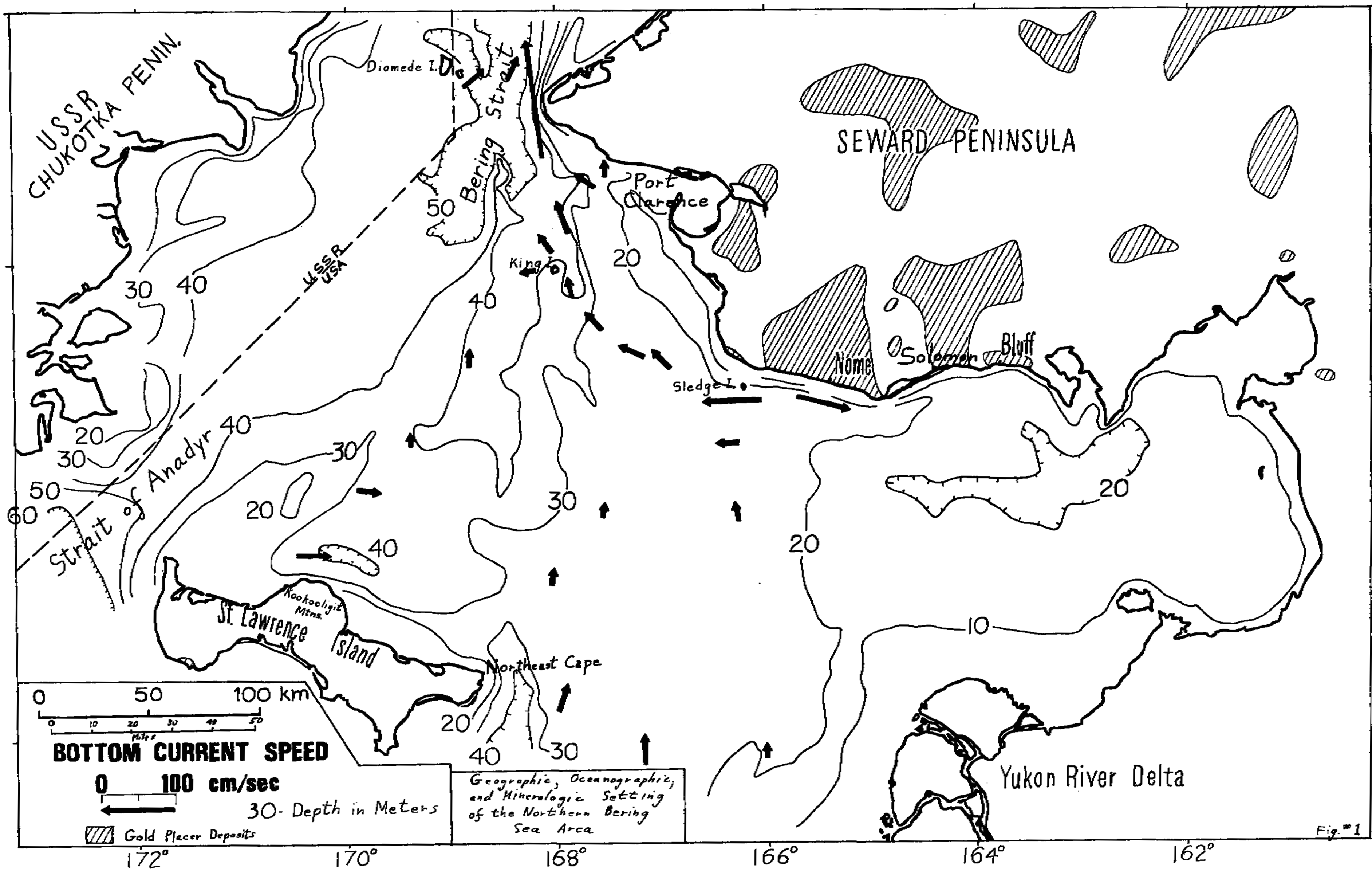
Several major and many minor placer tin and gold producing areas are found in Alaska near the shores of northern Bering Sea (Fig. 1) and therefore, the 25,000 square mile (65,000 square kilometer) submerged area encompassed within the Chirikov Basin east of the Russian-American Treaty Line seems a likely place in which to look for new tin and gold deposits. Resource-oriented studies of marine geology of the region were conducted during the summers of 1967 and 1968, as part of the Geological Survey's Heavy Metals Program. Our program included the following: recovery and study of about 700 bottom samples, a detailed sampling of segments of the beach at Nome

and Bluff, a reconnaissance sampling of beaches at Tin City, Wales, and Northeast Cape, seismic profiling, ship-borne magnetic studies, and examination of borehole cuttings from 51 drill sites near Nome (Fig. 2). Much of our data is still under study, and some of our

Figure 2 near here

results have already been reported elsewhere (Hopkins and Scholl, 1969; Greene, in press; Hopkins, et. al. in press; Tagg and Greene, in press; Hopkins, 1967a; Nelson and Hopkins, 1968). Detailed analyses of sedimentological parameters are still in progress for many of our bottom and beach samples, but most of the useful gold data is already available to guide continuing exploration for mineral resources in northern Bering Sea.

A great many individuals have assisted us in gathering the data for this report. We must make special mention of the hospitality and cooperation of scientists Dean McManus, Lee Bennet, and Richard Perry and of the technical and sailing crews of the R/V THOMAS G. THOMPSON (University of Washington), the R/V VIRGINIA CITY (U.S. Bureau of Mines) the OSS-1 OCEANOGRAPHER and OSS-32 SURVEYOR (United States Coast and Geodetic Survey) and the charter vessel M/V TOMCOD. Expert panning of the 1967 samples was done by Les Darrington of Placerville, California and Andrew Peterson of Nome, Alaska, and all of the 1968 samples were panned by Mr. Peterson. Procedures and techniques for studying the subvisible gold content of the bottom samples were developed by our colleagues Ray Martin and Kam Leong of the U.S. Geological Survey; other colleagues, Dick Tagg and John Schlee assisted in size analysis



USSR
CHUKOTKA PENIN.
Diomede I.
Bering Strait
USSR
USA
SEWARD PENINSULA
Port Clarence
King I.
Sledge I.
Nome
Solomon
Bluff
Strait of Anadyr
St. Lawrence Island
Kookooligit Mtns.
Northeast Cape
Yukon River Delta
0 50 100 km
BOTTOM CURRENT SPEED
0 100 cm/sec
30- Depth in Meters
Gold Placer Deposits
Geographic, Oceanographic, and Mineralogic Setting of the Northern Bering Sea Area
Fig. #1
66°
65°
64°
63°
172°
170°
168°
166°
164°
162°

and computer processing of data. We have benefitted greatly from extensive conversations and cordial cooperation with W. W. Wardward and A. H. Daily, formerly of Shell Oil Company; John Lord of American Smelting and Refining Company; and John Metcalfe, James Crawford, and Carl Glavinovitz of the United States Smelting, Refining, and Mining Company. Frank Wang was responsible for collecting samples in the closely sampled areas near Sledge Island and between Cape Nome and Bluff, and provided advice and councel concerning interpretation of the results. Discussions with Ralph Hunter provided the necessary information for statistical analysis of the data and he, C. L. Sainsbury and Frank Wang critically reviewed the manuscript.

Methods of Study

Our samples were collected on several cruises, and different techniques of analysis have been utilized because of the different circumstances. The methods of study are summarized in Table 1.

Table 1 near here

Nearly all samples have undergone preconcentration because of the need to avoid particle sparsity effects (Clifton et al., 1967). By preconcentrating large samples, we have attempted to remain within the suggested limits of statistical reliability for the relatively low concentrations and average particle sizes of gold that are present in the majority of samples (Moore and Silver, 1968; Clifton et al., 1969). In certain locations where very coarse gold (>1 mm) is found in coarse gravel (>2 mm) or where visible gold is responsible for low background values, particle sparsity effects have remained a problem even when large samples were preconcentrated before analysis. To help alleviate particle sparsity effects, moving averages have been calculated for the gold content of samples from densely sampled regions.

9.1287

Preconcentration generally was accomplished by screening out the gravel, and then siphoning off the silt and clay sized material to leave a subsample consisting mainly of sand and containing all gold more than 10 microns in diameter. The sand concentrates were panned, gold particles counted, and their size estimated (Table 2) for an immediate estimate of gold content. Subsequently, the pan concentrates

Table 2 near here

were analyzed by amalgamation or by atomic absorption techniques (Van Sickle and Larkin, 1968) to determine actual gold values. A few samples were pre-concentrated by using an elutriation technique to wash out silt and clay-sized particles of low density, leaving the gold and the coarser sediment (Martin, unpublished ms.) and this concentrate was then analyzed by atomic absorption techniques. Gold particle size was estimated for a few other samples by sieving the samples and then analyzing the total individual size fractions by atomic absorption techniques.

The continuing investigations of texture, mineralogy, and fossil content of Northern Bering Sea sediments will eventually permit detailed analysis of sedimentary environments, processes of deposition, and geologic history.

Oceanographic Setting

The Chirikov Basin is a shallow marine basin protected by land masses throughout most of its perimeter (Fig. 1 and 4). The eastern half is mostly less than 100 feet (30 meters) deep. Depths greater than 150 feet (45 meters) are found only in a deep channel off

Table 1. Methods of Study

Sample Source (Cruise)	Location Methods	Sampling Method	Typical Sample Size (kg)	Method of gold preconcentration	Au Analytical Method	Additional Analyses on Selected Samples	
Nome Beach (1967)						Texture, heavy minerals, lithology, roundness	Seismic refraction study of Nome Beach also completed (Greene, in press)
Bluff Beach (1968)	USGS Topographic Maps and Aerial Photos	Channel samples	5	panning	Color Count AA[1]	Texture heavy minerals	
Tin City and Wales Beaches (1967)					Color Count AA Emission Spectrometer		Sn content by Emission Spectrometer, wet chemical, and X-ray fluorescence is in progress
N.E. Cape Beach St. Lawrence Is. (1968)					Color Count AA		
R/V Virginia City (USBM) (1967)	Raydist, PRS (Precision Ranging System), Sextant	Shipek grab sampler, SCUBA Diver Becker drill, Sonico drill Drill cuttings flushed every 6-12' of drilling	2-5 5-10 9-12 kg Maximum sediment penetration of 244°	(A) 5mm screened out, remainder panned (B) Whole phi size fractions less than .5mm analyzed by AA	Color Count AA Amalgamation and weighing	Pebble lithology and roundness, texture, stratigraphic and lithologic correlation of drill holes	Clay, heavy mineral pollen, Foraminifera, Ostracoda, Mollusca, and radiocarbon dating studies in progress on selected drill samples.
R/V Thomas G. Thompson (U. of Wash) (1967)	Loran A Radar	10 gal. Van Veen Shipek, chain dredge	.5-10	Elutriation	AA	Texture, Mineralogy Foraminifera	
R/V OSS Oceanographer (1968)	Loran C, Radar, Satellite	Campbell Grab, 10 gal. Van Veen, box corer	10-30	2mm removed by screening		Studies of texture, heavy minerals, Foraminifera, Mollusca in progress, as well as studies of pebble roundness and lithology.	
OSS Surveyor (1968)	Radar, Raydist	10 gal. Van Veen	10-12	Clay and silt size removed by settling and siphoning techniques	Color count AA		
Tomcod (1968)	PRS	10 gal. Van Veen	10-30	panning			
Eskimo Skin Boat (1968)	Compass triangulation fixes	5 gal. Van Veen	5-10				

[1] Atomic Absorption analysis of gold as described by Van Sickle and Larkin (1968) and modified by Kam Leong at the Office of Marine Geology and Hydrology, Menlo Park, California

Table 2
Qualitative terms for particulate gold size and weight
(Compiled from data of J. C. Antweiler, personal commun., 1969; A. Dailey, personal commun., 1969; H. Higgenbottom, personal commun., 1967; Clifton, et. al., 1969; Hite, 1933)

	Color Size	Estimated* Modal Wt (in mg)	Estimated* Modal diameter (in mm) spheres	flakes‡	Comparable grain size
**Visible Gold	#1 Color	15	1.20	2.40	very coarse sand
	#2 Color	4	.70	1.40	coarse to very coarse sand
	#3 Color	1	.50	1.00	coarse sand
	#4 Color or very good trace	.3	.30	.50	medium sand
	Good trace	.03	.16	.30	fine sand
	Very fine trace	.003	.07	.125	very fine sand
Subvisible Gold	Ultra fine trace	.0001	.060	.100	very fine sand
	Smallest size particulate good observed	.000003	ca. .005 to	.010	very fine silt
	"Carlin type gold"		ca. .001		coarse clay

‡ Diameter approximately 10 x thickness

* Range of panners qualitative visual estimates probably is about ±50% in the #2 color to #4 color size classes; larger sizes are classified as 1¼, 1½ etc. - estimates for trace size colors are quite variable and probably range to over ±100%.

** Expert panning normally will recover 100% of visible gold; panning efficiency is quite variable and poor for subvisible gold.

Northeast Cape, St. Lawrence Island, in a small enclosed basin off the Kookooligit Mountains of St. Lawrence Island, and in parts of a broad trench-like feature that extends from Anadyr Strait to Bering Strait. Because the Chirikov Basin (Fig. 1) is rather protected, wave energy is low compared to the North Pacific. Moving ice covers the sea for about seven months of each year. Pressure ridges of ice occasionally become grounded in depths as great as 50-100 feet (15-30 meters) below sea level (Art H. Daily, personal commun.; Gene L. Bloom, personal commun.). Divers report that grounded ice "bulldozes" bottom sediment for short distances on the sea floor (H. G. Greene, personal commun.). Distribution of gravel-sized material, to be discussed later in the paper, suggests that pressure-ridge ice in contact with the sea floor may pick up bottom sediment and release it short distances away.

Strong currents of one knot or more move along much of the coastline, and bottom currents intermittently reach speeds of nearly three knots (150 cm/sec) in eastern Bering Strait (Fleming and Heggerty, 1966) (Fig. 1). In the Nome region, we find that bottom currents flow intermittently and suddenly at speeds up to nearly two knots (100 cm/sec) moving either eastward or westward parallel to the coast. Sparse observations in the central regions of Chirikov Basin have shown that relatively low current speeds prevail, and no currents stronger than 1/2 knot (25 cm/sec) have been reported to us.

Geologic setting

The Chirikov Basin spans several geologic provinces of pre-Tertiary rocks (Fig. 3). Most of Seward Peninsula is underlain by

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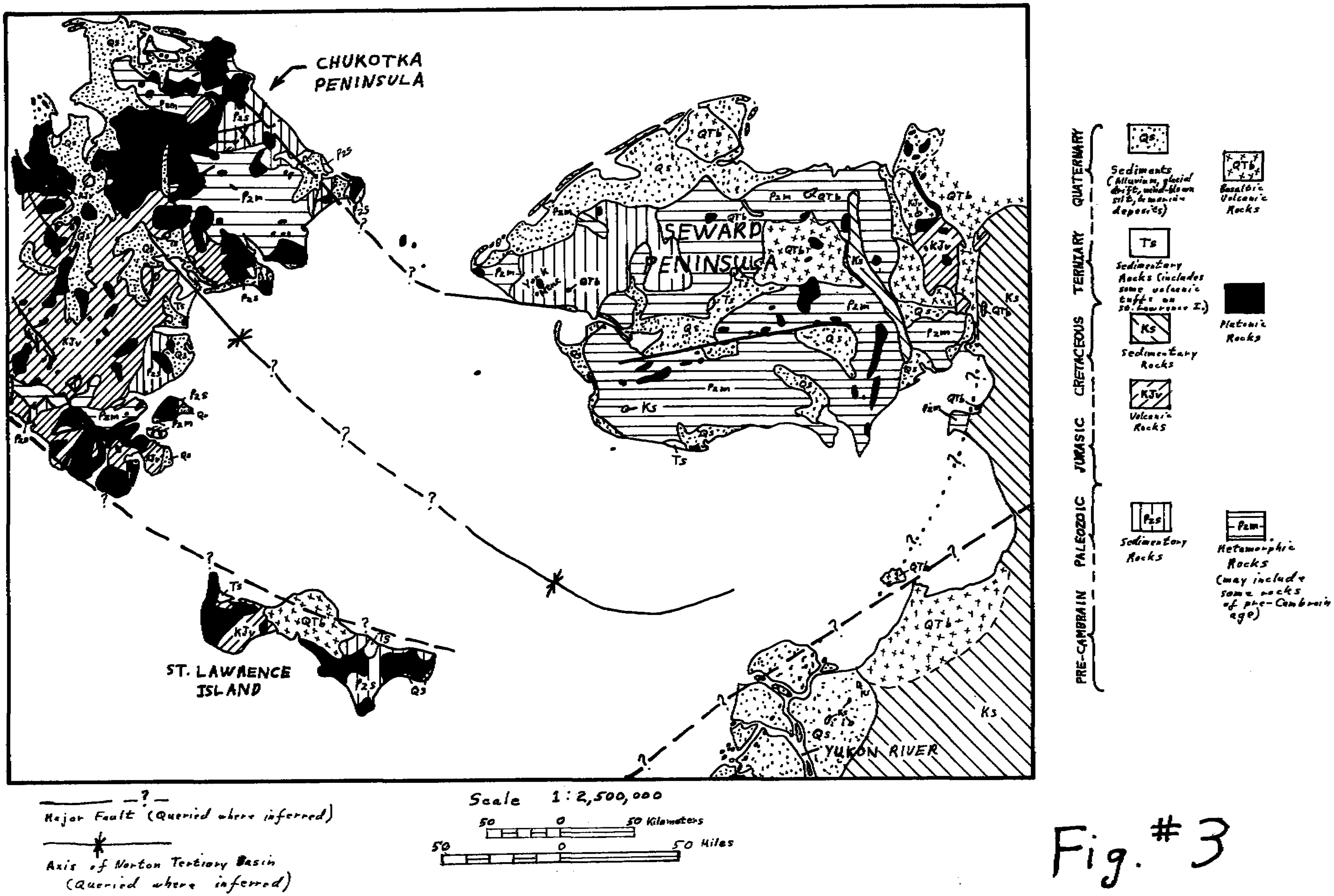

CHUKOTKA PENINSULA
SEWARD PENINSULA
ST. LAWRENCE ISLAND
YUKON RIVER
QUATERNARY
TERTIARY
CRETACEOUS
JURASSIC
PALEOZOIC
PRE-CAMBRIAN
Sediments (Alluvium, glacial drift, wind-blown silt, & mountain deposits)
Basaltic Volcanic Rocks
Sedimentary Rocks (includes some volcanic tuffs on St. Lawrence I.)
Plutonic Rocks
Sedimentary Rocks
Volcanic Rocks
Sedimentary Rocks
Metamorphic Rocks (may include some rocks of pre-Cambrain age)
Major Fault (Queried where inferred)
Axis of Norton Tertiary Basin (Queried where inferred)
Scale 1:2,500,000
50 0 50 Kilometers
50 0 50 Miles

Fig. #3

Figure 3 near here

metamorphic rocks of Pre-Cambrian ~~(?)~~ and early Paleozoic age, but unmetamorphosed limestone of Ordovician and Silurian age is thrust over the metamorphic rocks in the York Mountains of western Seward Peninsula. Northern Chukotka is underlain by a similar sequence of Pre-Cambrian and early Paleozoic metamorphic rocks, and these are overlain by later Paleozoic sedimentary rocks. Eastern St. Lawrence Island is composed of a sequence of gently folded and unmetamorphosed Paleozoic and early Mesozoic rocks. Western St. Lawrence Island and southern Chukotka are underlain by late Mesozoic volcanic rocks, but Paleozoic metamorphic and sedimentary rocks are exposed in local structural highs in southern Chukotka. Sharply folded Cretaceous sedimentary rocks, locally underlain by and interfingering with late Mesozoic volcanic rocks, dominate the eastern shore of the Chirikov Basin north of the mouth of the Yukon River. The Chirikov Basin itself is underlain by a prism of Tertiary sediments locally reaching thicknesses in excess of 6,000 feet (1800 meters) (Scholl and Hopkins, 1969). The Tertiary sediments extend onto present-day land areas in part of St. Lawrence Island and Chukotka.

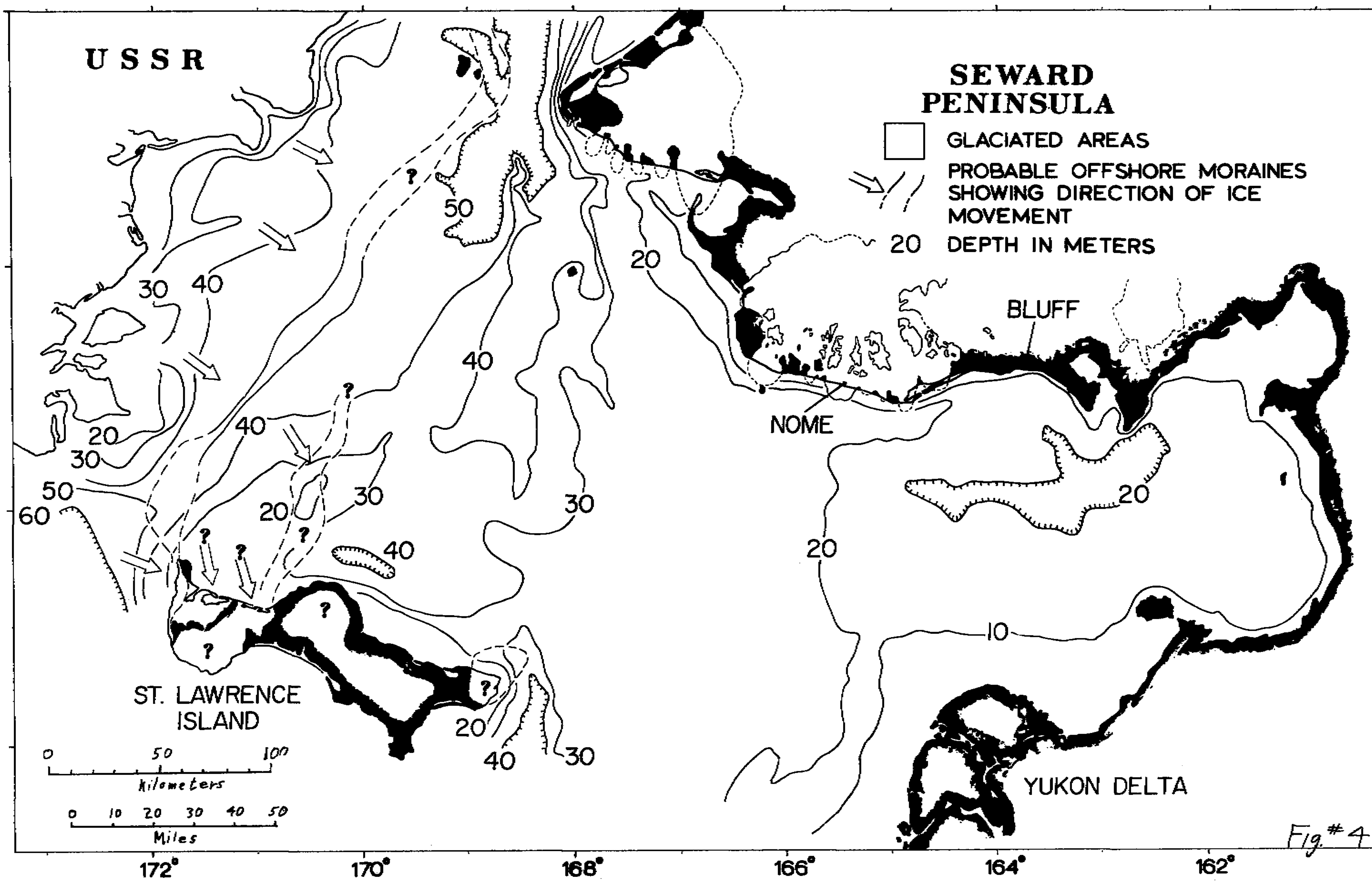
The major gold-placer district at Nome and several other minor placer districts lie very near the present shores of Seward Peninsula and near the southwest corner of St. Lawrence Island (Fig. 2). Gold placer districts may lie near the east coast of Chukotka, as well, but we have no precise information on locations of mineralized areas there. Profitable gold placers are rarely found more than 6 to 12

miles (10 to 20 kilometers) from bedrock sources, as Emery and Noaks (1968) have emphasized. Thus, the most promising areas in which to search for submerged placers are those that lie near the known placer areas on land. However, small amounts of fine gold probably can be dispersed great distances. Detrital gold in the central part of the Chirikov Basin must have been derived mainly from the surrounding land areas, because potential bedrock sources beneath the basin, itself, are mostly buried deeply beneath the nearly undeformed Tertiary sediments.

Geologic studies on Seward Peninsula indicate that glaciers have played an important role in dispersing and redistributing pre-existing gold placers there, and so we have devoted considerable effort to delineating the chronology and extent of past glaciation in the northern Bering Sea region (Fig. 4). Glaciers appear to be an agent

Figure 4 near here

of mass transport that carries coarse gold particles long distances from the bedrock sources, though with increasing dilution as the distance from the source increases. Evidence from seismic profiling (Tagg and Greene, in press) and from the drill holes show that glaciers originating in the hills and mountains north of Nome have extended short distances beyond the present shoreline. The lower hills and small mountain ranges of western Seward Peninsula also have supported large glaciers that evidently extended short distances beyond the present shore. Chukotka Peninsula has been inundated by glacial ice that extended well beyond the present shoreline (Petrov, 1967).


USSR
SEWARD PENINSULA
GLACIATED AREAS
PROBABLE OFFSHORE MORAINES SHOWING DIRECTION OF ICE MOVEMENT
20 DEPTH IN METERS
NOME
BLUFF
ST. LAWRENCE ISLAND
YUKON DELTA
0 50 100
kilometers
0 10 20 30 40 50
Miles
172°
170°
168°
166°
164°
162°
66°
65°
64°
63°
Fig. # 4

At the time that our studies began, we assumed that the floor of the Chirikov Basin had never been heavily glaciated. However, dredge hauls in 1967 and surface sediment sampling in 1968 resulted in the recovery of apparent glacial drift in areas well away from the present shore of Chukotka; high resolution seismic profiling turned up a series of linear belts of disturbed sediments interpreted as submerged and partly buried glacial moraines (Grim and McManus, in press). Coastal exposures of glacial drift overlying Pleistocene marine sand and gravel had been discovered ~~by D.S.Mc~~ on a barrier bar of Nyrakpak Lagoon on the western shore of St. Lawrence Island in 1966 (D.S. McCulloch, unpublished field notes, 1966). A re-examination by Hopkins in 1968 resulted in the recognition of thrust structures in the marine sediments and erratic boulders in the till that suggest that the drift was deposited by glacier ice that encroached from offshore. It now appears that glacial ice originating in Siberia once covered a large area in the western part of the Chirikov Basin and that these glaciers spread onto present-day land areas of northwestern St. Lawrence Island.

STUDIES NEAR NOME

General Geology

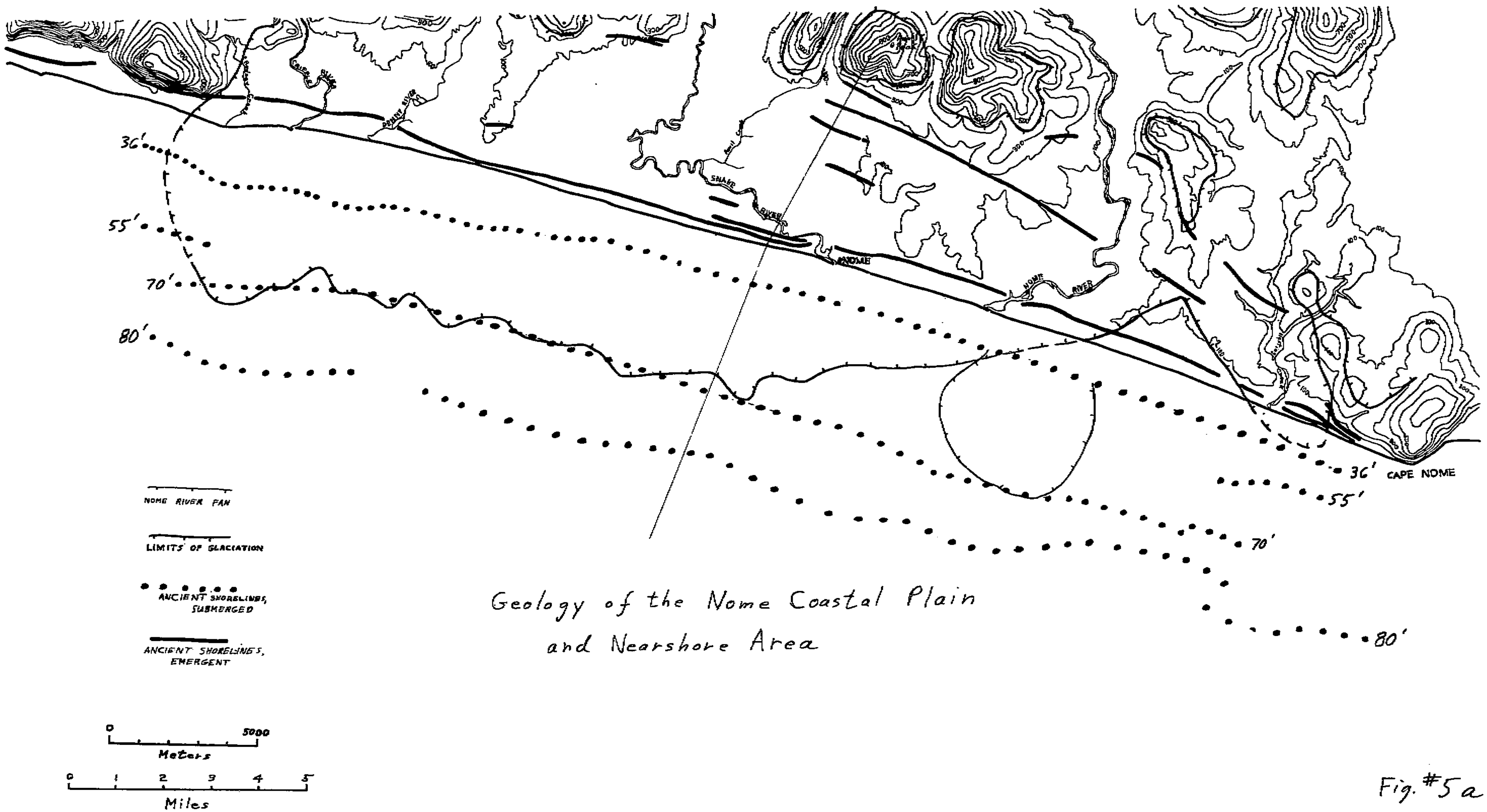
Knowledge of gold and sediment distribution in the Nome area will be considered first because it is most complete and it can serve as a model for later discussion on the remainder of Chirikov Basin. A geologic map and cross-section based upon onshore geologic mapping and upon our offshore studies, shows that bedrock lies just below the sea bottom off Cripple River in the western part of the area, but that it

is deeply buried beneath Quaternary and older sediments further east (Fig. 5). Fine-grained marine sediments of late Tertiary and Quaternary age cover the deeply buried bedrock offshore, and a series of late Tertiary and Quaternary continental and shoreline deposits rest on bedrock near the modern shoreline and beneath the coastal plain. The ancient beach deposits have yielded much of the past gold production in the Nome area.

The coastal plain at Nome has been overridden by glacial ice on at least two occasions, and the glaciers extended several miles seaward of the present coast line in the area between the mouths of Nome River and Rodney Creek (Fig. 5). The first glaciation apparently took

Figure 5 near here

place during early Pleistocene time, and the last during the Illinoian glaciation; the much smaller glaciers of the Wisconsin glacial age failed to reach the coastal plain at Nome (Hopkins, MacNeil and Leopold, 1960). The glaciers eroded mineralized bedrock and older alluvial placers in the hills north of Nome, and they excavated segments of the older beach placers on the coastal plain; consequently small quantities of gold are consistently dispersed within the glacial drift. Our offshore seismic reflection profiles (Tagg and Greene, in press) and the offshore drilling shows that the glaciers sheared into the underlying marine beds there; the result has been the formation of an intercalcated series of layers of glacial till and marine clayey silt at the margin of the offshore glaciated area (Fig. 5).



Geology of the Nome Coastal Plain and Nearshore Area

Fig. #5a

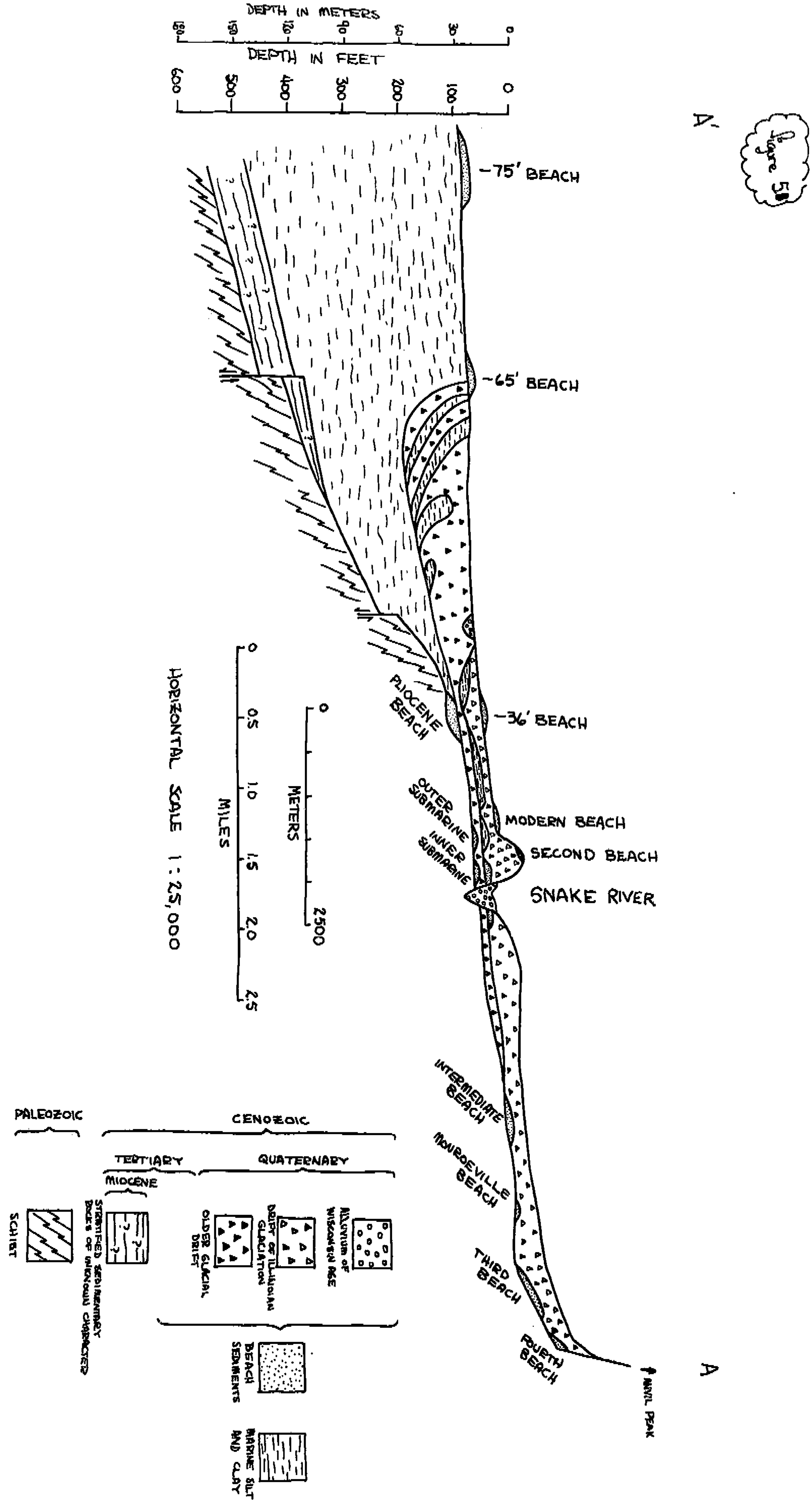


Figure 5B
A'
A
DEPTH IN METERS
0
30
60
90
120
150
180
DEPTH IN FEET
0
100
200
300
400
500
600
-75' BEACH
-65' BEACH
-36' BEACH
PLIOCENE BEACH
OUTER SUBMARINE
INNER SUBMARINE
MODERN BEACH
SECOND BEACH
SNAKE RIVER
INTERMEDIATE BEACH
MONROEVILLE BEACH
THIRD BEACH
FOURTH BEACH
ANVIL PEAK
METERS
0
2500
MILES
0
0.5
1.0
1.5
2.0
2.5
HORIZONTAL SCALE 1:25,000
PALEOZOIC
CENOZOIC
TERTIARY
QUATERNARY
MIOCENE
SCHIST
STRATIFIED SEDIMENTARY ROCKS OF UNKNOWN CHARACTER
OLDER GLACIAL DRIFT
DRIFT OF ILLINOIAN GLACIATION
ALLUVIUM OF WISCONSIN AGE
BEACH SEDIMENTS
MARINE SILT AND CLAY

In the Pleistocene times of lowered sea level a large fan of outwash gravel was built off the present mouth of the Nome River. Also, stream valleys eroded during low sea level episodes can be traced in the offshore area as discontinuous channels and chains of irregular depressions, now partly filled with Holocene muds.

The subaerial deposits on the sea bottom have been affected by wave handling during periods when sea level has risen to or above its present position. Beach deposits younger than the drift are found at an altitude of about 30 feet (9 meters) onshore and at depths of -35 to -42 feet (-11 to -13 meters), -65 to -72 feet (-20 to -22 meters) and about -80 feet (-25 meters) offshore. Beach gravel is also present off Cape Nome at a depth of about -55 feet (-17 meters), but no ancient shoreline can be traced continuously across the Nome area at this depth. The onshore beach at 30 feet (9 meters) locally called "Second Beach", was formed during the Sangamon Interglaciation (Hopkins, 1967); the age of the submerged beaches is uncertain, but that at -70 feet (-21 meters) may have formed during a temporary slight rise in sea level about 30,000 to 40,000 years ago, and the others may have formed during the Holocene rise in sea level between 15,000 and 5,000 years ago. Both "Second Beach" and the modern beach at Nome have been extensively mined for gold, and therefore the submerged beaches should be attractive exploration targets. Net longshore drift is eastward along the present beach in the Nome area, and the distribution of gold in the older beaches on the coastal plain suggests that longshore drift was also predominantly eastward when they were formed. Trends in pebble size,

pebble roundness, and quartz content indicate that the eastward coastal drift predominated during the formation of the submerged beaches, as well (D. M. Hopkins, unpublished data). Pebbles derived from morainal and outwash areas have been carried eastward along the submerged beaches and deposited in linear belts extending across areas generally underlain by marine silt and clay.

Bottom Sediment

Distribution of bottom sediment near Nome (Fig. 6) is determined

Figure 6 near here

by interaction of the strong longshore and offshore currents with sediment supplied at the beach, by the distribution of bodies of subaerial sediment left from earlier glaciers and streams, and by the effects of past wave action upon these subaerial sediments when the shoreline transgressed and regressed over the region. A narrow belt of well-sorted medium sand, evidently actively moving along the coast, extends from the modern strand to depths of -20 to -30 feet (-6 to -9 meters). Offshore from the transgressive sand, gravel is found in an irregular belt parallel to the shore and in seaward lobes where morainal, outwash, alluvial, and bedrock areas extend furthest from shore. The gravel pattern is interrupted by tongues of finer sediment extending landward in the topographic lows and by small patches of well sorted medium sand (Fig. 6). Divers report that in the relict-sediment area, gravel is exposed in high topography and that minor depressions are generally filled with well-sorted sand; these reports explain the patchy distribution of sand in the relict gravel region, and they suggest that

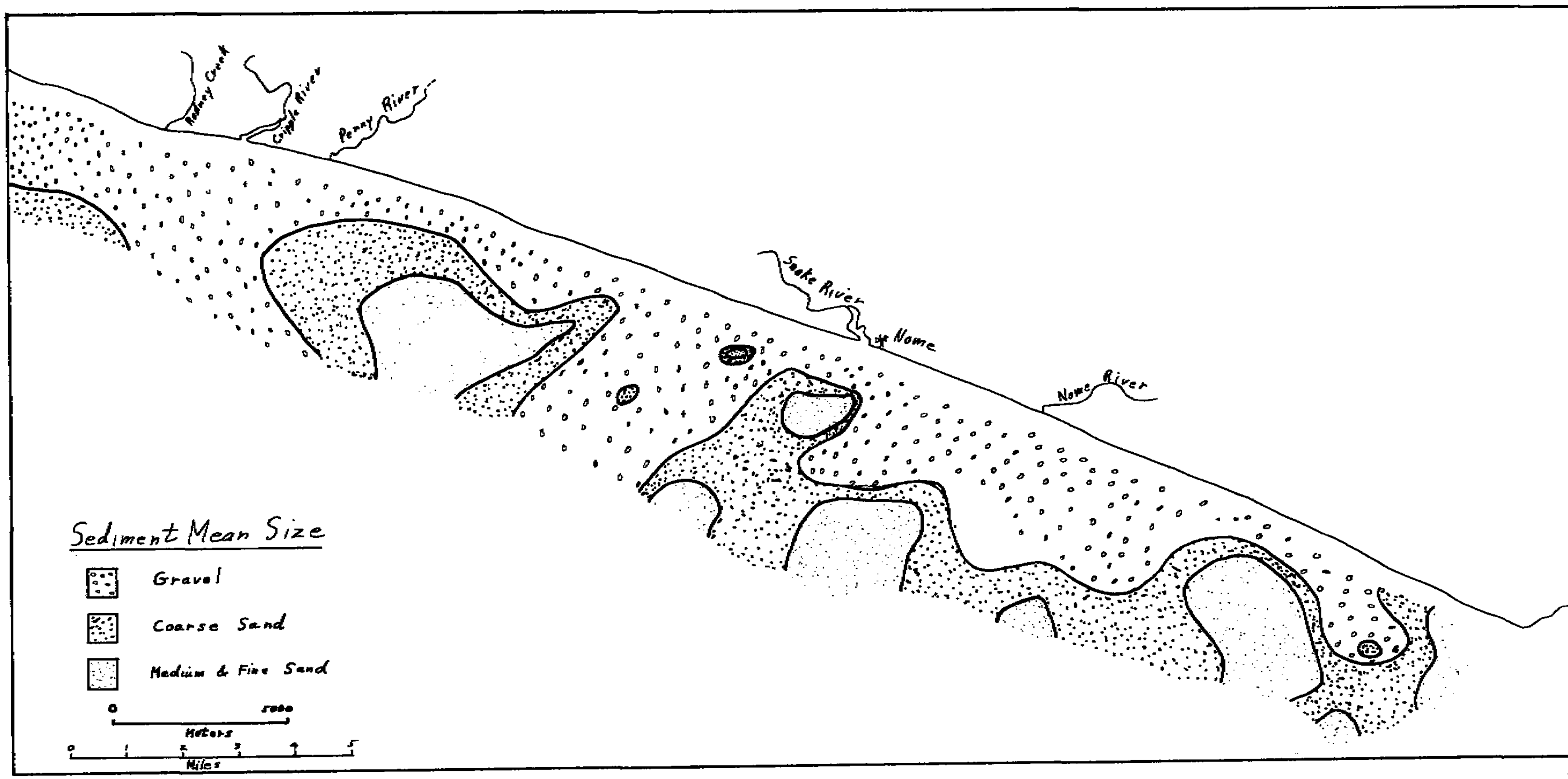
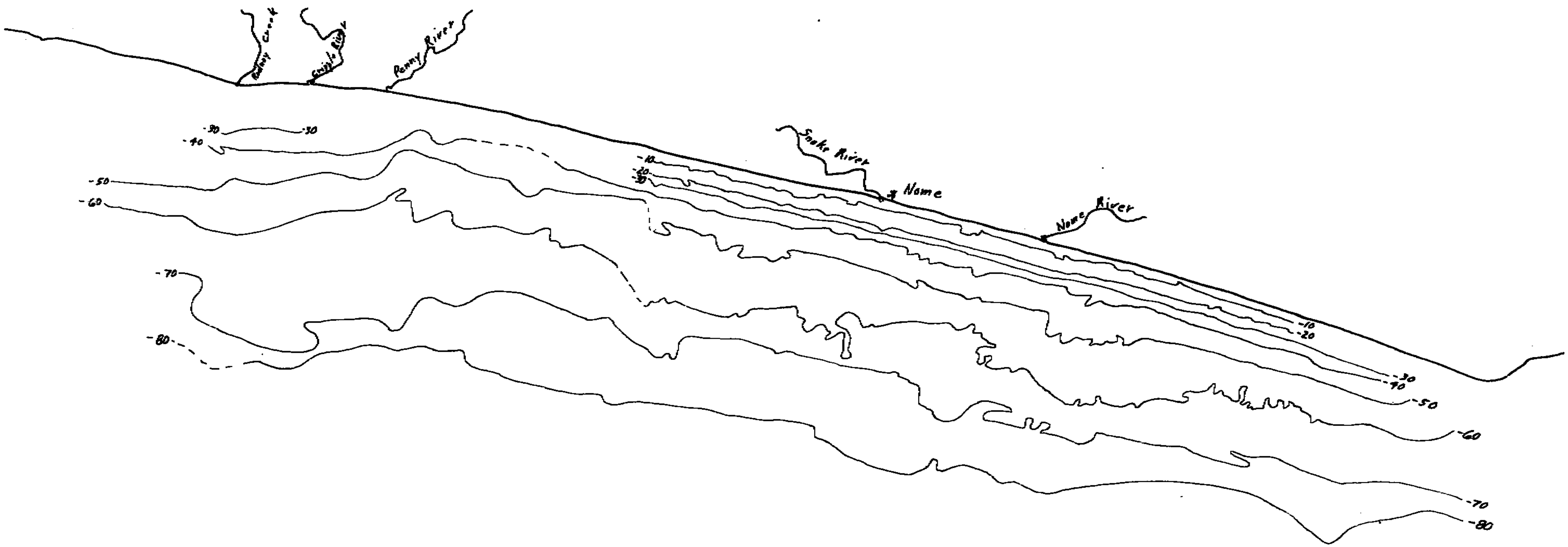
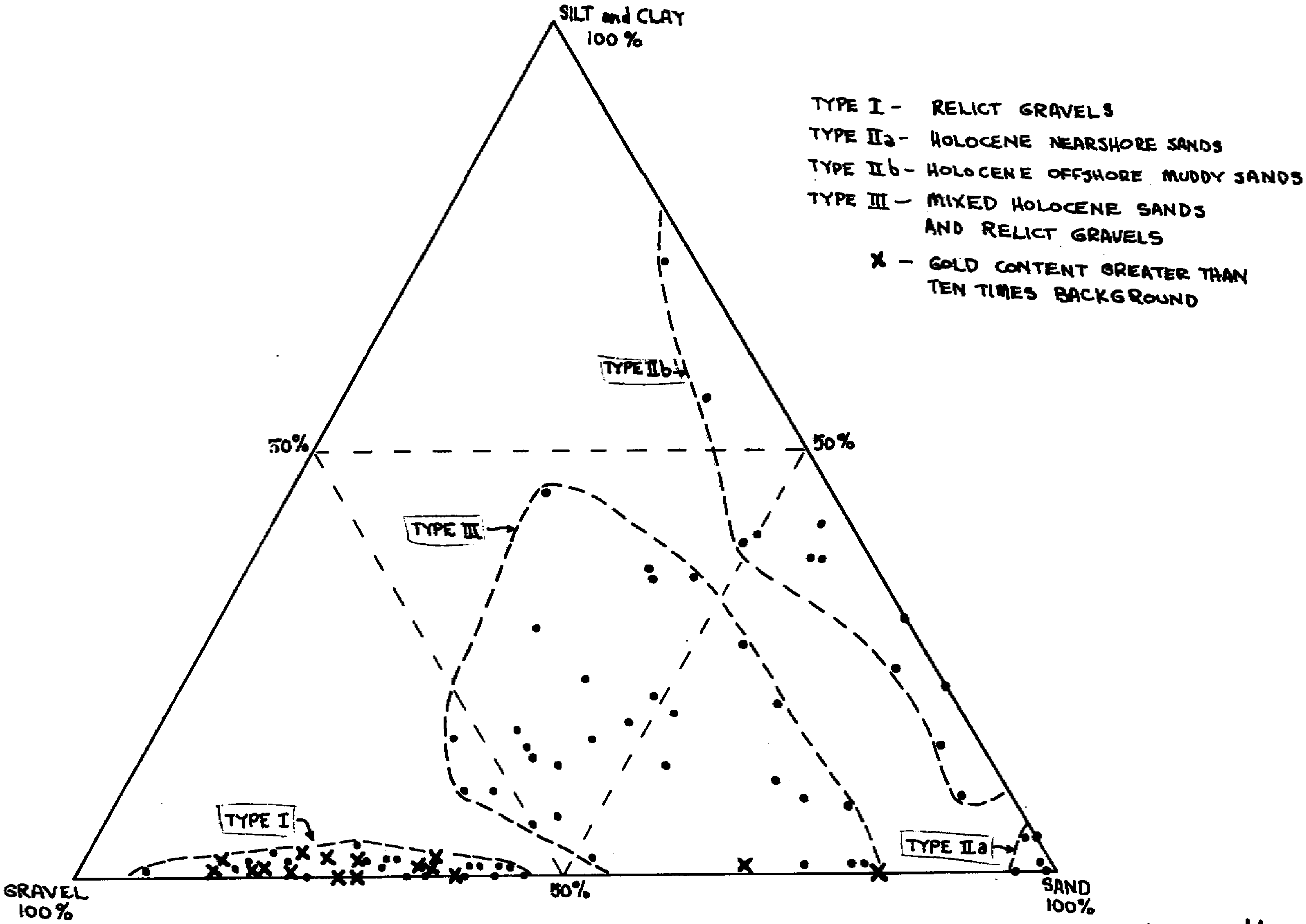

Rodney Creek
Cripple River
Penny River
Snake River
Nome
Nome River
Sediment Mean Size
Gravel
Coarse Sand
Medium & Fine Sand
0
5000
Meters
0
1
2
3
4
5
Miles

Fig. #6a,

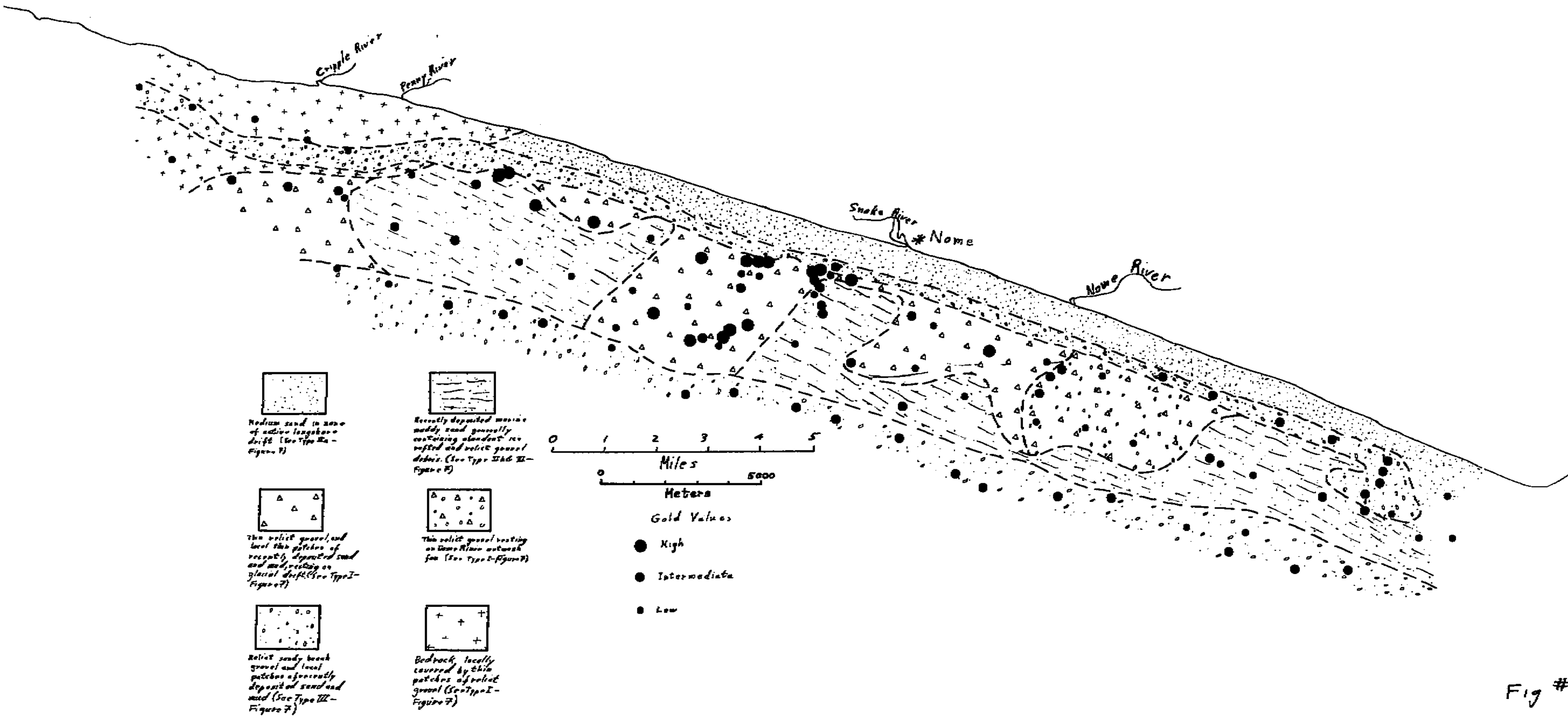


Nome Nearshore Bathymetry



SILT and CLAY
100 %
TYPE I - RELICT GRAVELS
TYPE IIa - HOLOCENE NEARSHORE SANDS
TYPE IIb - HOLOCENE OFFSHORE MUDDY SANDS
TYPE III - MIXED HOLOCENE SANDS AND RELICT GRAVELS
X - GOLD CONTENT GREATER THAN TEN TIMES BACKGROUND
TYPE IIb
50%
50%
TYPE III
TYPE I
TYPE IIa
GRAVEL
100%
50%
SAND
100%

Fig. #7



Cripple River
Penny River
Snake River
Nome
Nome River
Medium sand in zone of active longshore drift (See Type IIa - Figure 7)
Recently deposited marine muddy sand generally containing abundant ice rafted and relict gravel debris. (See Type II & III - Figure 7)
Thin relict gravel, and local thin patches of recently deposited sand and mud, resting on glacial drift (See Type I - Figure 7)
Thin relict gravel resting on Nome River outwash fan (See Type I - Figure 7)
Relict sandy beach gravel and local patches of recently deposited sand and mud (See Type III - Figure 7)
Bedrock, locally covered by thin patches of relict gravel (See Type I - Figure 7)
0 1 2 3 4 5
Miles
0 5000
Meters
Gold Values
High
Intermediate
Low

Fig #8

9.1287

the strong bottom currents (Fig. 1) prevent sediment deposition on the highs and deposit sand in the topographic lows. The gravel and sand patches form a thin mantle resting on more typical and less well-sorted till, outwash, and alluvium. The sorted surface gravel apparently was formed by past wave action which winnowed out fine sediment during shoreline transgression and regression. Seaward from the relict-gravel areas, the bottom sediments grade from muddy sand to clayey silt with few or no pebbles.

Thus, four general types of surface sediment can be distinguished (Fig. 7), and general surficial geology can be summarized (Fig. 8). Relict sediment containing more than 50% gravel lies in areas where

<u>Figure 7 and 8 near here</u>

transgressions and regressions of the shoreline have winnowed fine particles from till, outwash, alluvium, or weathered bedrock, and where strong currents have prevented Holocene deposition. Shoreward of the relict gravels, well-sorted and medium-sized transgressive sand, of Holocene age, containing 10% or less of silt and clay lies in the present-day zone of longshore current movement. Seaward of the relict gravel zones, Holocene muddy sand grades offshore to clayey silt. A mixed sediment type of Holocene mud and relict gravel occurs near the boundaries of the relict gravel areas and where small local depressions in the relict gravel region are covered by a thin mantle of recent mud. Submerged beach remnants have no distinct sediment type because they were cut indiscriminately across varied older marine and continental deposits at depths of -35 to -42 feet (-11 to -13

meters) and -65 to -72 feet (-20 to -22 meters). They can only be distinguished by topographic and seismic expression and rounding and lithology of the gravel fraction.

Distribution of Gold

Though this report is concerned primarily with gold in the surficial sediments, a summary of the vertical distribution of gold encountered in the Bureau of Mines drill holes provides some insight into the origin and significance of gold concentrations found at the sea bottom. Gold concentrations commonly are low or even lacking on bedrock. The fine-grained marine deposits encountered in the drill holes rarely contain any visible gold. The glacial till, however, consistently carries small values, averaging about $.10 per cubic yard (70 parts per billion- ppb 1/) as it does onshore. Interstratified outwash and alluvium at the base of stream channels within the drift commonly contain gold concentrations greater than the average values in the till. Some buried beach gravel also contains appreciable gold concentrations. But the highest gold values in the drill holes generally were those encountered in the first six-foot increment of drilling. And even higher values per unit volume were recovered in our surface samples, many of which were obtained while the R/V VIRGINIA CITY was anchored at a drilling station.

Among the surface sediments, the highest gold values and the coarsest gold particles are found in the relict residual gravel on the glacial drift (Fig. 8, Table 3). Gold values that are low but consistently above background are found in surface samples from

1/ Parts per billion is abbreviated to ppb in remainder of the report. Based on a price of $35 per ounce for gold, 10 ppb is equivalent to 1 cent per ton, or 1.6 cents per cubic yard.

9.1287

submerged beach ridges. Most bottom samples recovered from the surface of the Nome River outwash fan, and from the Holocene sand and mixed sediments of the topographic lows contain only a few fine gold particles and their gold content is only slightly higher than the regional background valùes found throughout northern Bering Sea.

The largest sized particles of gold occur on the drift and are as much as several mm in diameter; however, high values in samples are mainly caused by #3 size colors, which average 1 mm in diameter and 1 mg in weight (Table 2). In general, gold values in samples containing more than 100 times the regional background value result from gold particles in the medium to coarse sand size; other samples, including those whose values represent the background, derive their value from gold particles of fine sand size.

Samples from much of the relict gravel resting on glacial drift contain gold in quantities well above the regional background values, and large parts of the drift area are mantled by a veneer of gravel containing gold in quantities that are economically interesting. Samples were recovered that contain as much as $4.00 (2500 ppb) in gold per cubic yard, and about one third of the samples contain more than $1.00 per cubic yard (600 ppb) in gold.

The relict gravel on the drift is relatively thin. Divers reported a thickness of only a few inches in some places, and our box cores and grab samplers sometimes recovered stratified samples in which poorly sorted silty glacial till lay beneath less than six inches (15 centimeters) of well sorted relict gravel. In other places, the

relict gravel may be as much as two feet (60 cm) thick, judging from comparsions between the lithology and gold content in the first six-foot (two meters) increment of drill cuttings and the lithology and gold content of grab samples obtained at the same anchorage. Overall, the average thickness of the relict gravel layer on the drift probably is about one foot (30 cm).

The gold in the relict gravel is obviously derived from the underlying drift, but gold in many places is about ten times as abundant in the relict gravel as in the drift. The relict gravel on till shows evidence of wave handling, and we believe that it was formed by the winnowing out of fine and light particles from the drift at times when the shoreline migrated across the drift areas during periods of rapidly rising or falling sea level. The gold concentration factor of 10 in much of the surficial gravel suggests that about 10 feet (3 meters) of glacial drift was removed to form this relict deposit. On the other hand, an average gravel thickness of about one foot and an average gravel content of about 25% in the underlying till indicates that less than five feet of till has been eroded off by transgression or regression of the shoreline.

The shoreline features detected at depths of -35 to -42 feet (-11 to -13 meters), locally at -55 feet (-17 meters), at -65 to 72 feet (-20 to -22 meters), and at about 80 feet (-25 meters) evidently represent positions where sea level changed less rapidly and where the shoreline was stablized long enough to form well-defined beach ridges and shore cliffs. Among these, the beaches at -65 to -72 feet (-20 to -22 meters) and at -55 feet (-17 meters) were sampled most thoroughly, the -35 to -42 foot (-11 to -13 meters) beach was sampled in only a few places, and the -80 foot (-25 meter) beach was sampled in only one place. The gold content of surface samples from the submerged beaches is much lower than the gold content of the relict gravel layer on the drift (Table 3); the richest sample contained only \$.10 per yard (58 ppb) in gold values. Though visible gold was recovered in most samples ~~even~~ up to one mm in size the gold consists mostly of trace-sized colors, comparable in size to those characterizing the modern beach. The gold content is generally highest in places where the submerged beaches cross the glacial drift, and gold values generally diminish eastward from points where the beaches intersect the drift. Trends in pebble size, roundness, and lithology indicate the submerged beach ridges were constructed by eastward longshore drift (Hopkins, unpublished data). This movement transported coarse material along with small amounts of trace-sized gold particles eastward from the lobes of glacial drift and from the areas of shallow bedrock west of Rodney Creek. Coarse sediments were also contributed to the submerged beaches by the Nome River outwash fan.

Though surface grab samples from the submerged beaches show relatively low gold values, better concentrations may be present at depths of a few feet. Seismic reflection profiles crossing the submerged beaches show internal structure comparable to the modern beach (Tagg and Greene, in press). Sediment thickness as large as 10 feet (3 meters) are detected along the axial part of the submerged beaches,

but the beach gravel is much thinner at the seaward edges and perhaps at the landward edges, as well. The mean thickness of beach sediments in the submerged shoreline areas shown on figure 5 is probably about 5 feet (1.5 meters).

The same processes that resulted in strong gold concentrations in the thin layer of relict wave-handled gravel on the drift should have produced comparable gold concentrations in the well-defined submerged beaches in places where they consist mostly of material reworked from auriferous drift deposits. Small-scale gold-mining operations on the modern beach at Nome have, in recent years, recovered fine gold from laminae of black or garnet-rich sand that lay a foot or more below the beach surface. The best concentrations encountered during the extensive beach mining conducted early in this century commonly lay at the base of the prism of beach sediments, several feet below the beach surface. Our bottom samplers have been incapable of penetrating to depths comparable to those at which good gold concentrations are commonly found in the modern beach.

Relict gravel on the Nome River outwash fan contains relatively little gold in the areas where we sampled it. The richest sample has about \$.02 of gold per cubic yard (10 ppb), and the average gold content in these samples was even lower (Table 3). Several samples possess visible gold in trace-sized colors, but none contained coarse gold. Better concentrations may be present in the basal part of some of the glaciofluvial and alluvial gravel. Boreholes obtained by the R/V VIRGINIA CITY failed to encounter significant gold concentrations at depth in the Nome River outwash fan, but some bodies of submerged and buried alluvium did have significant gold concentrations. Mining operations on land have shown that the best gold concentrations in alluvial and outwash gravel generally lie at the base of the deposit, and the upper part is commonly relatively sterile; gold is generally evenly dispersed in glacial till. Thus, it is not surprising that the thin veneer of wave-handled gravel mantling the Nome River outwash fan contains much less gold than does the wave-handled gravel veneer on the till.

The marine muddy sand and the mixed sediment commonly contain small quantities of gold in particles ranging from trace to subvisible size (Table 2); the values and gold particle size are comparable to those found in most other bottom sediments throughout the Nome region (Table 3). Because gold particles of a millimeter or more in diameter are nearly restricted to relict gravel over glacial drift and because the richer samples are confined to the drift area, the glacial till is probably the principal source of gold in the offshore area. Since visible gold generally is absent from muds immediately seaward of Nome (see Table 4, samples ANc 238-240; 248-250) but is common in muds east and west of the drift areas, it appears that the trace-sized gold particles have been moved laterally from the drift along with other fine sediment. This wide dispersal of small gold particles in sandy and muddy bottom sediment probably was accomplished by longshore currents and longshore drift when sea level was lower than at present.

Thus, the distribution and particle size of gold in our bottom samples near Nome indicates that the gold is mostly derived from the unsorted sediments of glaciers that had eroded gold-bearing bedrock and older placers landward of the present shoreline. A thin deposit of relict gravel greatly enriched in gold was created in areas where the shoreline migrated rapidly across the drift; thicker beach deposits were formed where the shoreline was temporarily stable, but the gold concentrations in these thicker deposits, if present, lie below the depths to which our samplers penetrated. Gold concentrations in the bodies of alluvial and outwash gravel, if present, lie below the depths reached by our samplers and also below the depths reached by eroding waves during transgressions of the sea; thus the wave-handled gravel layer mantling the areas of alluvium and outwash gravel contains much smaller concentrations of gold than the veneer of wave-handled gravel on the glacial till. However, minor quantities of gold, apparently carried by longshore drift laterally from the till areas, have been deposited in Holocene beach gravel, sands, and muds resting on older outwash, alluvium, or marine sediments.

Pressure ridges of sea ice that have grounded in gold-bearing gravel and then raised during high tides and storm surges may also have moved minor quantities of gold and occasional large gold particles into areas that would otherwise be nearly barren.

<u>Economic possibilities</u>

Nearly all of our samples at Nome were obtained within the three mile limit, in areas that are held by private individuals under prospecting and mining permits; thus, we cannot discuss the economic possibilities of specific areas. However, we can state that some areas of thin relict gravel on glacial drift appear to contain sufficient gold to merit consideration as possible mineable ore bodies, and that, although our surface samples do not define any mineable deposits in the areas of submerged beach ridges, geologic reasoning suggests that such deposits may exist at depths of less than 10 feet (3 meters) below the sea bottom. Ore deposits in other areas, if present, probably lie at greater depths. Future prospecting for shallow placer deposits in the Nome area should focus primarily upon the "skin deposit" on the drift, and upon thicker basal gravel of now-submerged beaches in areas where the beaches are composed mostly of material reworked from the glacial drift.

Gold values in our samples from the main drift area are erratically distributed, but nearly all samples contain gold in quantities well above regional background values, and some are very rich. The variability of values per unit volume is partly due to the presence of local thin patches of relatively barren, current-deposited sand or mud, covering the richer relict gravel, and partly due to the particle-sparsity effect in samples too small to be representative. Samples from one 6-square mile area have an overall average value of $1.48/cu. yd. (920 ppb), consisting mostly of #3 colors (1mm diameter). Clifton and others (1969) show that more than 55 lbs. (25 kg) of sediment are required to obtain a representative sample in material containing gold of this particle size and in this abundance.

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Our samples in the Nome area ranged in weight from less than 2 lbs. (1 kg) to nearly 45 lbs. (20 kg.), but most weighed less than 11 lbs. (5 kg). To compensate for inadequate sample weights, we have calculated moving averages of gold values for groups of samples from similar sedimentary environments. A mean value was calculated for samples collected from each square-mile area in an arbitrary grid.

Moving averages were then calculated by averaging the values in each square-mile area with those in square-mile areas to the east and west, and this average value was plotted in the central grid square. Because the original sample pattern consisted of samples collected on a one-mile grid plus added samples at borehole drilling sites, each mean value was based on a minimum of three samples, and most were based on five or more samples. The average total sample weight upon which moving-average calculations were based was 65 lbs. (30 kg). The resulting average values for each sedimentary environment are given in Table 3.

Detailed statistical analysis of the data suggests that reliable estimates of gold tenor have been obtained for the richest 6-square mile area of the study. A comparison of cumulative frequency distribution curves for individual and for moving-average gold values indicates that particle sparsity effects are greatly reduced by using moving-average data (Fig. 9). Contrasting the actual or observed

Figure 9 near here

cumulative frequency distribution curves with the expected curves calculated from the Poisson distribution in a manner similar to that of

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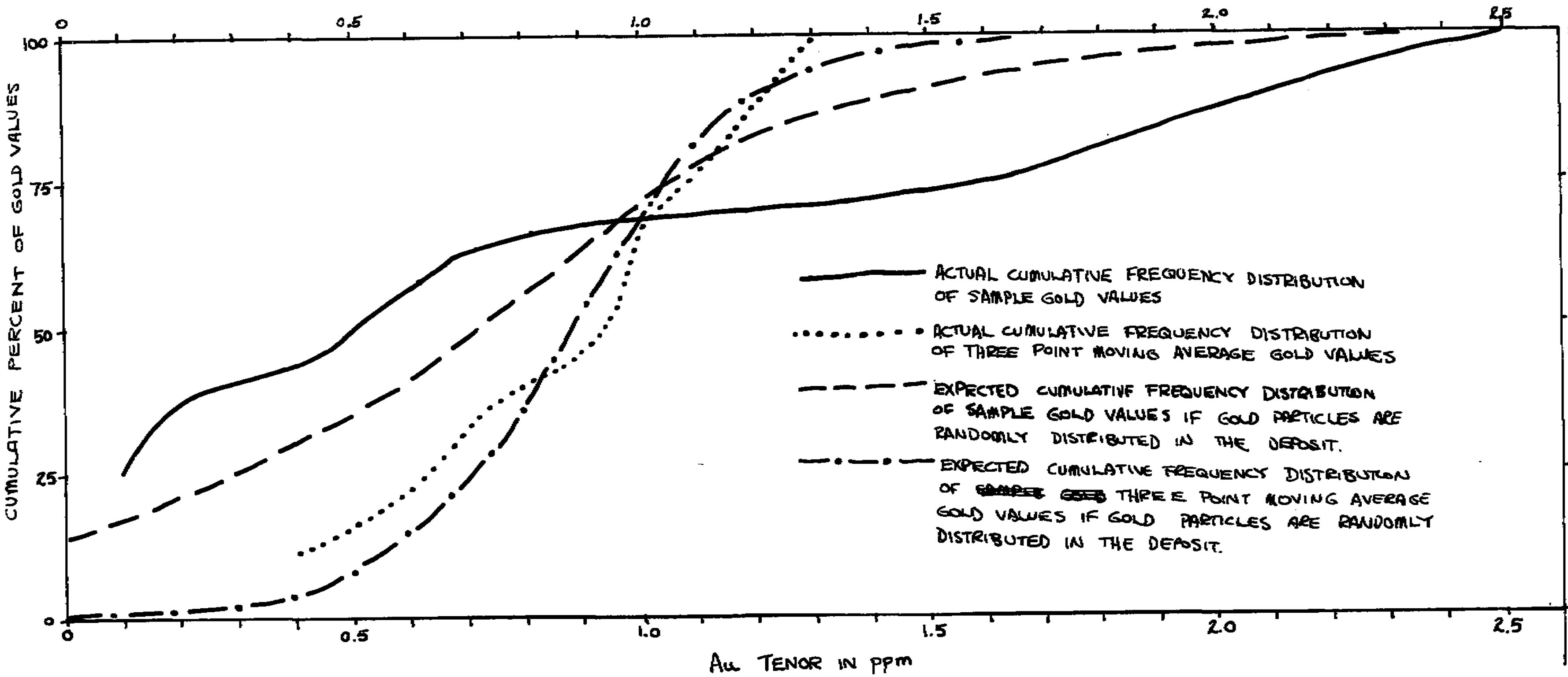

NEARSHORE NOME GOLD VALUE FREQUENCY DISTRIBUTION

Fig #9

Griffiths (1960) gives an estimate of the randomness of gold distribution. The distribution of sample gold tenors can be expected to follow a binominal distribution, which is approximated by the Poisson distribution, if the particles are randomly distributed through the deposit (Clifton, et. al., 1969). In calculating the expected curves, we assumed that the gold tenor of the 6-square mile area was equal to the 920 ppb average of all samples from the area.

The closeness of fit between expected cumulative frequency distributions of gold tenor and actual cumulative frequency distribution indicates that the actual distribution is consistent with the hypothesis that the gold tenor of the six square mile area is 920 ppb and that the gold particles are randomly distributed through the area. Although the closeness of fit was not tested statistically, it appears qualitively very good for the moving-average gold values. This suggests that the reliability of the estimated gold tenor of the area is very high. If, as this qualitative test suggests, the gold is randomly distributed, then moving-averages calculated for samples having aggregate weights of 30 kg, which would essentially eliminate particle-sparsity effect, should have 95% of the values between 570 ppb and 1,840 ppb. The entire distribution of the moving average values falls between 400 and 1,300 ppb; this again suggests that gold distribution of the deposit approaches a random distribution and that the average ore tenor is close to 920 ppb.

All of these data point to the strong possibility that large areas on the drift are mantled by relict gravel of sufficient volume and gold content to be mineable at a profit, and they emphasize the value

of large, closely-spaced bottom samples in the delineation of "skin deposits" of gold-bearing gravel. The total mineable yardage cannot be reliably estimated because average thickness and exact lateral extent of the rich "skin deposits" have not been adequately established by our few drill holes, and because offshore mining costs are unknown. The total yardage available would be reduced or enlarged if the average thickness of the highly auriferous relict gravel is significantly smaller or larger than our estimate or if much of the partially buried and unsampled relict gravel surrounding the known 6-square mile area, also is highly auriferous. A major problem in mining rich "skin deposits" would be the requirement that only the thin, surface residuum be excavated. If substantial quantities of the underlying drift were excavated in the course of mining the surficial wave-winnowed gravel, the average values would be lowered as a result of dilution by material having a much lower gold content.

Our samples of the surface gravel on the submerged beaches contain an average of only $0.03 per cubic yard (16 ppb) in gold but as we have noted, the best concentrations in the deposits along the well-defined submerged shorelines are likely to lie below the reach of our sampling equipment. The submerged beaches definitely merit continued exploration using boring equipment that can penetrate gravel and sand to depths of 10 or 15 feet below the sea bottom. Because the pay streaks are likely to be relatively narrow (not wider than 500 feet and possibly as narrow as 100 feet), boreholes should be closely spaced. Attention should be focussed primarily upon areas where the submerged beaches are in contact with the glacial drift. Gold-bearing material in the drift probably becomes increasingly diluted by incorporation of older marine mud with increasing distance from the shore. Therefore, the beaches that rest on drift close to shore probably are more promising than those at greater distance from the shore.

STUDIES ELSEWHERE IN THE CHIRIKOV BASIN

The association of high gold values with coarse, relict sediments noted offshore at Nome hold true in other parts of the Chirikov Basin, as well. However, no other area in the Chirikov Basin has yielded samples as rich as the richest samples at Nome, and samples from some relict gravel areas are essentially barren. Fine-grained sands throughout the Chirikov Basin occasionally contain visible gold and in places define relatively high regional background, although they do not constitute a recoverable resource by the standards of present-day mining technology.

Bottom sediments

Bottom sediments in the eastern part of the Chirikov Basin consist of silty clay apparently derived from the Yukon River, and the western part of the basin is mostly floored by compact, fine silty sand of unknown origin (MacManus, Creager, and Kelly, in press) (Fig. 10).

Fig. 10 near here

Seismic profiling indicates that the silty sand of the western part of the basin can be traced eastward beneath the clayey silt from the Yukon River (Grim and MacManus, in press); evidently, Yukon-derived sediments are encroaching upon the silty sand, and this suggests that the silty sand is a relict deposit formed under environmental conditions that differ from those prevailing in the Chirikov Basin at the present time.

Coarser sediments are found in nearshore areas along Seward Peninsula and St. Lawrence Island, in Bering Strait, and in several areas well away from shore in the west-central part of the basin (Fig. 10).

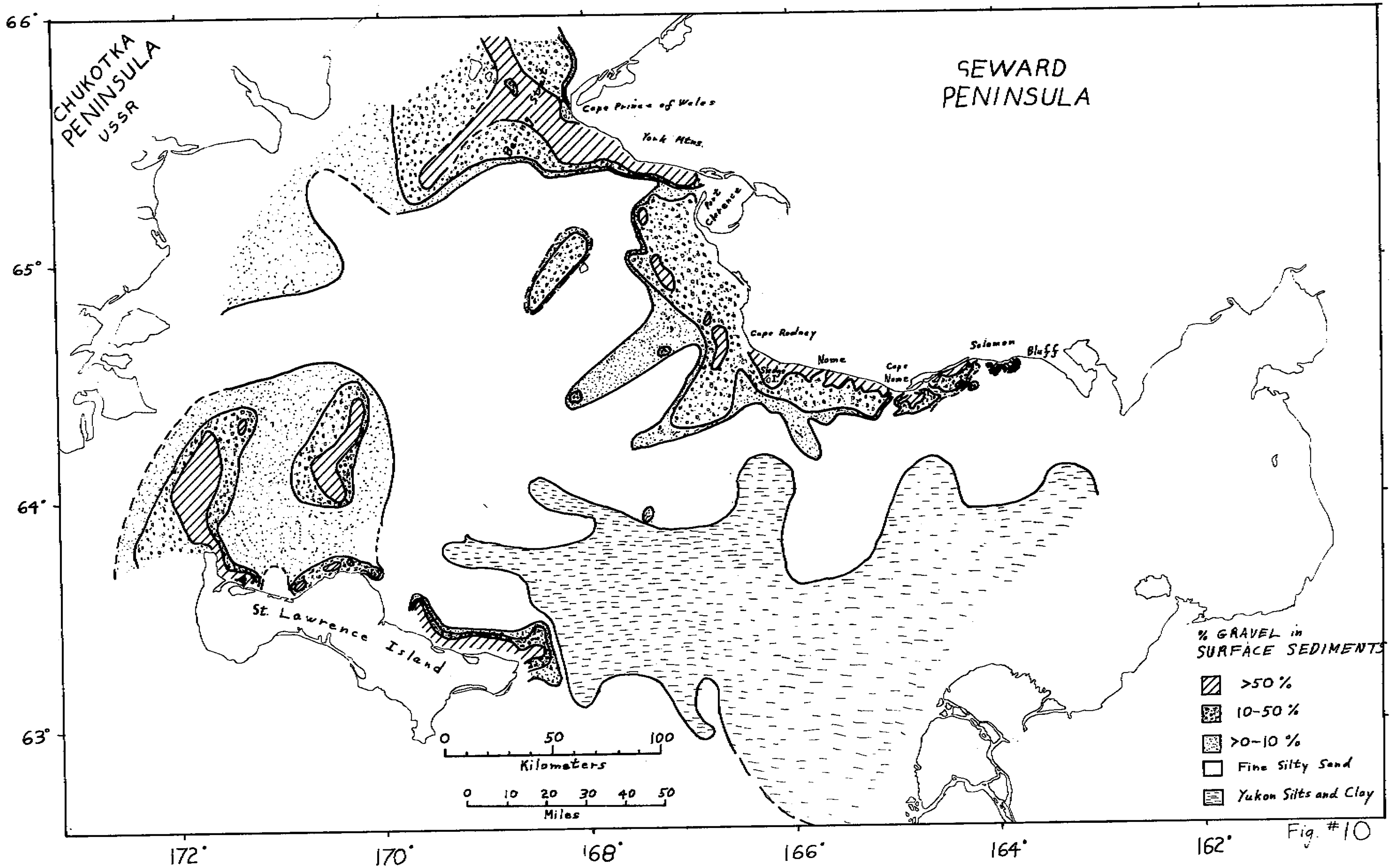
CHUKOTKA PENINSULA USSR
SEWARD PENINSULA
Cape Prince of Wales
York Mtns.
Port Clarence
Cape Rodney
Nome
Cape Nome
Solomon
Bluff
St. Lawrence Island
66°
65°
64°
63°
172°
170°
168°
166°
164°
162°
0 50 100
Kilometers
0 10 20 30 40 50
Miles
% GRAVEL in SURFACE SEDIMENTS
>50 %
10-50 %
>0-10 %
Fine Silty Sand
Yukon Silts and Clay

Fig. #10

These sediments have not been studied in as great detail as the Nome sediments and consequently our conclusions as to their origin may be revised as our studies progress.

The small patches of coarse gravel near Topkok Head and Bluff probably reflect the presence of submarine outcrops of bedrock. Coarse relict sediments in the nearshore area between Solomon and Cape Nome probably are derived from morainal deposits and a fringing outwash apron deposited by glaciers that extended to or slightly beyond the shoreline in this area. Our seismic profiling and bottom sampling suggests bedrock is either exposed or buried beneath a very thin cover of coarse sediment, largely of local origin, in the area extending from Rodney Creek past Sledge Island to the vicinity of the mouth of the Sinuk River. A very wide nearshore tract of coarse sediments is found in the area between Sledge Island and the entrance to Port Clarence. Our sampling of this shoal region has been concentrated at its outer fringe, and we have not yet undertaken seismic profiling there. We speculate, however, that this is an area of shallow bedrock extending westward from the Kigluaik Mountains, and that the bottom in this area is mantled by outwash, alluvium, and detritus from local bedrock. The coarse sediment offshore along the south coast of Seward Peninsula between Port Clarence and Cape Prince of Wales probably includes reworked glacial detritus (Fig. 10) as well as material eroded from shallow submerged outcrops. A large sea valley extending westward along the coast from Port Clarence to Bering Strait probably is covered with alluvium. Both glacial drift and sediment tentively indentified

as alluvium have been recovered from the floor of Bering Strait. The belts of gravel extending southwestward from Bering Strait toward St. Lawrence Island and southwestward from a point west of King Island probably mark the crests of morainal ridges built by glaciers that originated in Siberia. These are buried beneath younger deposits along part of their extent (Grim and MacManus, in press) but they reappear as patches of gravel bottom nearer the coast of St. Lawrence Island (Fig. 10). From the Kookooligit Mountains eastward to Northeast Cape, the coarse sediments near the north coast of St. Lawrence Island appear to be derived from submerged bedrock outcrops. We recovered coarse alluvium in a dredge haul from the bottom of the deep channel east of Northeast Cape and glacial drift in a dredge haul from a higher area that lies to the east of the deep channel.

<u>Gold distribution in coarse sediments</u>

More than a third of the samples recovered in the area of coarse sediments between Cape Nome and Solomon contain visible fine traces of gold, and one sample off the mouth of the Solomon River contained a #4 color. Values per cubic yard, however, are generally low, and richest sample contains gold values of only a few cents per cubic yard. The Solomon River and its tributaries have produced considerable placer gold, but gold placers are only sparsely distributed elsewhere between Solomon and Cape Nome; the largest particles of gold in the offshore area probably were moved offshore by glaciers that scraped through pre-existing placers and associated mineralized bedrock on-land. Some fine trace-size gold particles may have a similar source, but it is also likely that much trace-sized gold was transported from the offshore Nome sources by longshore drift during lowered sea levels.

The Sledge Island area proved to be difficult to sample because of the coarse size of the bottom gravel and the presence, in some places, of outcrops at the sea floor. No samples were obtained at many of our stations within 3 to 5 km (2 to 3 nautical miles) of the Seward Peninsula coast. At the remaining stations, nearly half of our samples contained visible particles of gold of fine trace size, and several samples contained #3 colors. The richest sample contained about $.50 per cubic yard (318 ppb) in gold value by color count (Table 3). The relatively high values in the Sledge Island area are surprising, because gold placer deposits are only sparsely distributed on the mainland nearby. The best values were found in our outer sampling lines, suggesting that the gold is derived from local and previously unrecognized areas of mineralized bedrock in the offshore area.

About a third of the bottom samples from the area between Cape Rodney and Point Spencer contain visible gold and several of these contain #3 or #4 colors. The richest sample contains about $.14 per yard (87 ppb) in gold. These samples, too, were collected offshore from a land area in which productive placers are small and sparsely distributed. The presence of coarse gold in fair abundance well offshore suggests that mineralized bedrock may be present at the sea bottom nearby.

Number 4 sized colors, that may be gold, were seen during panning of samples from the south coast of western Seward Pensinula between Point Spencer and Cape Prince of Wales. These panning values were not confirmed by AA analysis, but the very low AA values found probably are unreliable because of the unusual treatment given this particular series of samples. They were ground to a fine powder so that a small split could be taken for emission spectrograph analysis for tin; it appears that present AA techniques cannot adequately analyze such a fine powder (Kam Leong, personal commun., 1969). For this region, color counts probably are the best data available and give a maximum value of 93 ppb and an average areal value of $0.007 per cubic yard (42 ppb). Small maximum size of gold particles and gold tenor of sediments in this area do not suggest any offshore gold sources.

Fine gold was recovered in samples from the beach at Northeast Cape, and some of our bottom samples offshore from Northeast Cape contain gold in trace-sized particles, but the gold content of these samples is less than $.01 per cubic yard (3 ppb).

Several samples recovered near the coast of western St. Lawrence Island and from the morainal gravel areas to the north contained bright metallic particles up to 1 mm in diameter that were taken to be gold during our panning. The richest of these samples according to color count had a value of $.40 cubic yard (259 ppb) (ANc 86, Table 4); but unfortunately the pan concentrate was lost before any confirming AA analysis could be run. AA analysis of the other samples in the region revealed no significant amounts of gold. A microprobe analysis of

Table 3. Comparative parameters of gold values in surface sediment types of the different Northern Bering Sea regions.

Region (General Sediment Type)	Approximate Visible Au Size: Max[1] color size (mm)	Approximate Visible Au Size: Mode[2] (mm.)	50th percentile of pannable particulate gold values within region (in ppb)[3]	Max Au Value (in ppb)	Average Au Value for Total Sediment Area[5] (in ppb)	No. samples
Nome Nearshore Surface Sediments						
(Relict Gravel over Till)	#2 (1.4)	1.0	114.0	2,500.0	556.0	34
(Relict Gravel over Outwash)	GT (.3)	.062-.25	3.0	12.0	4.0	7
(Relict Gravel over Bedrock)	—	—	0.0	0.0	0.0	4
(Holocene sands and muds)	VGT (.6)	.062-.6	3.0	24.0	8.0	19
(Submerged sandy beach Gravels)	#3 (1.0)	.062-.3	3.0	58.0	16.0	45
Modern Nome Beach						
(Beach Gravels)	#2 (1.4)	.125-.250	5.0	1,910.0	155.0	
(Selected Ruby Sands)	#4 (0.6)	.062-.250	117.0	13,000.0	2,118.0	20
Bering Sea Nearshore (excluding Nome)						
Solomon - Bluff						
(Holocene Sediment)	#4 (.6)	.3-.6	0.2	38.0 (104.0)[4]	2.0	92
C. Nome - Solomon						
(Relict Sediment)	GT (.3)	.3	0.3	26.0	1.0	87
Sledge Island						
(Relict Gravels)	#3 (1.0)	.6-1.0	0.9	36.0 (318.0)	4.0	30
C. Rodney - Pt. Clarence						
(Relict Gravels)	#3 (1.0)	.6-1.0	0.2	31.0 (87.0)	2.0	30
Pt. Clarence to C. Prince of Wales						
(Relict Gravels)	#4 (0.6)	.3-.6	0.1	3.0 (13.0)	(4.2)[4]	52
North Shore St. Lawrence						
(Relict Gravels)	VFT (.13)	.13	0	2.0 (3.0)	0.1	28
Open Bering Sea						
(Relict Morainal Gravels)	#3 (1.0)	.13-1.0	0.1	38.0 (259.0)	2.0	22
(Sands and Muds)	VFT (.13)	.13	0.1	182.0	3.0	186

Table 3. Comparative parameters of gold values in surface sediment types of the different Northern Bering Sea regions.

1/ Based on gold color counts (See Table 2) of pan concentrates (VGT = very good trace, GT = good trace, VFT = very fine trace).

2/ Size mode of visible size Au responsible for greatest value in samples.

3/ 50th percentile value of gold value cumulative frequency distribution (See Figure 12) for each given region and sediment type. Therefore 50% of the samples in each local region are between 0 and the 50th percentile value and this range represents tha local back ground value for particulate panned gold.

4/ Value that is in parenthesis is based on color count estimate that was not confirmed by AA analysis. Lack of AA confirmation may be due to erroneous color count originally, loss of gold particles during sample transfer from pan to container, one container to another container, and transport from the field to analytical labs in Menlo Park in complete solution of gold while processing for AA test (K. Leong personal commun., 1969).

5/ Based on only AA data.

Table 4. Gold and sediment data for Northern Bering Sea samples more than 3 nautical miles from the shoreline

Sample No.	Latitude	Longitude	Sample Wt. (kg.)	Color Count	Color Count est. ug	Color Count ppb	AA Au (ug)	AA Au ppb	Precent Gravel	* Remarks
THOMPSON CRUISE 1967										
TT18-11	63°56.8'	162°20.4'	0.6				6.5	12.0	0	
" 13	64°08.5'	163°05.6'	0.1				3.0	23.0	0	
" 17	62°46.5'	165°25.0'	0.6				17.4	31.0	---	
" 21	63°02.0'	166°48.0'	0.2				6.0	25.0	0	
" 23	63°08.0'	167°20.0'	0.9				9.6	11.0	0	
" 24	63°10.0'	167°32.0'	0.6				16.4	27.0	0	
" 25	63°16.0'	168°00'	0.3				20.0	66.0	0	
" 29a	65°21.0'	167°09.0'	1.3				40.6	23.0	22	
" 29b	65°21.0'	167°09.0'	.2				0.0	0.0	20	
" 31	65°13.1'	167°27.0'	0.4				8.6	20.0	0	
" 44a	64°38.0'	170°36.2'	0.6				10.2	16.0	0	AA with elutriation
" 44b	64°38.0'	170°36.2'	0.8				5.4	7.0	0	AA total sample
" 45	64°01.2'	169°02.0'	0.2				9.6	45.0	0	
" 47	65°51.0'	169°33.0'	1.4				13.5	9.0	0	

1/Values are based on the estimated weight of the visible gold (see Table 2) and the weight of the background gold found by AA analysis. These samples had anomalously low AA values compared to their visible gold content. This discrepancy was either due to loss of gold particles before AA analysis and/or to incomplete solution of larger particles during AA analysis. These "best estimate" values have been utilized in Figure 9.

2/AA analysis shows that size of gold traces was difficult to distinguidh and that the average microgram content of gold trace was 16.5 or the mid-point between average content from a good and a very fine trace (see Table 2). Consequently, the average value of 16.5 ug has been used in evaluation, gold content from color counts.

Table 4 continued

Sample No.	Latitude	Longitude	Sample Wt. (kg.)	Color Count	Color Count est. ug	Color Count ppb	AA Au (ug)	AA Au ppb	Percent Gravel	* Remarks
SURVEYOR CRUISE 1968										
SU 139	63°24.7'	168°27.8'	5.3	1finetr.	16.5	3.1	12.0	2.3	17	
" 141	64°12.5'	168°05.7'	6.3	—	—	—	27.6	4.4	0	
" 142	64°37.5'	167°55.4'	2.6	1finetr.	16.5	6.4	30.0	11.5	0	
" 143	65°10.8'	167°44.0'	4.9	4finetr.	66	13.4	6.5	2.9	0	13.8*
" 147	64°04.5'	164°00.0'	4.6	2finetr.	33.0	7.2	14.4	3.2	0	
OCEANOGRAPHER CRUISE 1968										
ANC 73	65°37.7'	168°20.9'	36.8				3.9	0.1	57	
" 74	65°37.0'	168°28.7'	31.2				0.8	.03	53	
" 75	65°32.0'	168°46.0'	19.9				2.6	0.1	10	
" 76	65°27.0'	168°56.0'	9.1				4.0	.4		
" 77	65°19.5'	169°32.0'	28.0						68	
" 78	65°04.3'	169°34.39'	22.7				3.5	.2	0	
" 79	64°51.0'	169°50.0'	31.5				—	—	0	
" 80	64°47.2'	169°42.5'	23.0				7.0	.3	0	
" 81	64°40.0'	169°33.4'	25.2	3 fine tr.	49.5	1.97	2.4	0.1	<1	2.0*
" 82	64°32.9'	170°06.4'	20.4				2.0	0.1	<1	
" 83	64°27.0'	170°21.0'	10.7				0.8	0.1	35	

Table 4 continued

Sample No.	Latitude	Longitude	Sample Wt. (kg.)	Color Count	Color Count est. ug.	Color Count ppb	AA Au (ug)	AA Au ppb	Percent Gravel	* Remarks
OCEANOGRAPHER CRUISE CONTINUED										
ANC 84	64°23.5'	170°12.0'	21.3				2.9	.1	54	
" 85	64°20.14'	170°01.78'	16.6				1.0	.1	2	
" 87	64°01.4'	170°27.0'	13.3				9.1	.7	59	
" 88	64°03.9'	170°30.8'	24.9				2.6	.1	50	
" 89	64°08.0'	170°36.0'	13.2				2.5	.2	48	
" 90	64°02.8'	171°02.8'	12.1				2.1	.2	—	
" 91	64°03.0'	171°24.8'					2.7		—	
" 94	63°54.0'	171°42.0'	14.4				2.1	.1	77	
" 120	63°39.8'	170°01.5'	15.1				1.0	.1	0	

Table 4 continued

Sample No.	Latitude	Longitude	Sample Wt. (kg.)	Color Count	Color Count est. ug.	Color Count ppb	AA Au (ug)	AA Au ppb	Percent Gravel	* Remarks
OCEANOGRAPHER CRUISE CONTINUED										
ANC 122	63°37.2'	169°57.5'	25.1				0.7	.2	0	
" 124	63°33.9'	169°53.6'	18.1				0.4	<.05	0	
" 125	63°33.6'	169°49.0'	12.4				0.5	<.05	0	
" 126	63°32.0'	169°44.6'	16.0				1.0	.1	0	
" 127	63°31.8'	169°40.0'					3.7	.2	57	
" 128	63°30.8'	169°37.0'	16.0				1.2	.1	44	
" 129	63°28.5'	169°35.0'	11.9						86	
" 145	63°20.5'	168°40.0'	27.1	3 fine tr.			0	0	17	
" 146	63°24.0'	168°37.0'	10.6				3.0	.3	7	
" 147	63°28.0'	168°32.0'	29.3				1.5	.6	0	
" 148	63°~~35.0'~~ 35.8'	168°26.5'	11.6				1.5	.1	0	
" 149	63°30.5'	168°58.5'	12.7				3.0	.2	0	
" 150	63°37.0'	169°10.0'	23.0				1.8	.1	0	
" 151	63°41.0'	169°28.0'	6.2				1.1	.8	0	
" 153	63°49.0'	169°40.0'	8.5	1 finetr.	16.5	19.4	5.2	.6	0	
" 154	63°50.0'	169°47.0'	12.3				1.0	.8	0	
" 155	63°52.8'	169°54.4'	16.2	1 fine tr.	16.5	1.0	25.0	1.5	0	

Table 4 continued

Sample No.	Latitude	Longitude	Sample Wt. (kg.)	Color Count	Color Count est. ug	Color Count ppb	AA Au (ug)	AA Au ppb	Percent Gravel	* Remarks
OCEANOGRAPHER CRUISE CONTINUED										
ANC 156	64°02.02'	169°02.70'	19.9				1.2	.1	0	
" 157d	64°08.05'	169°30.84'	16.2				6.5	.4	0	
" 157e										
" 158	64°12.48'	169°47.33'	32.2				2.0	.1	0	
" 159	64°17.47'	169°20.21'	23.6	few fine tr.	49.5	2.1	3.8	.1	0	
" 160	64°22.53'	168°51.67'	29.4				1.5	.1	0	
" 161	64°33.85'	169°02.86'	31.5	few fine tr.	49.5	1.6	7.7	.2	0	
" 162	64°41.5'	169°12.2'	16.0				2.6	.2	0	
" 163	64°43.8'	169°59.5'	11.8				2.0	.2	0	
" 164	64°49.0'	168°28.5'	35.3				2.9	.1	11	
" 165	64°54.6'	168°03.5'	12.3	many fine tr.	66	5.4	119	9.7	0	
" 166	64°57.0'	167°49.0'	21.3	1 #4 &fine tr.	330	15.4	2.6	0.1	0	
" 167	65°04.0'	168°00.0'	32.5	many fine tr.	66	2.0	7.8	.2	12	
" 168	65°10.0'	168°13.0'	29.2				1.3	< 0.05	0	
" 169	65°15.0'	168°25.0'	22.6				0.5	<0.05	0	
" 170	65°23.0'	168°39.0'	14.2				2.5	.2	0	
" 172	65°24.0'	168°19.1'	15.8				2.1	0.1	19	
" 173	65°17.0'	168°07.5'	19.3				2.4	0.1	0	

Table 4 continued

Sample No.	Latitude	Longitude	Sample Wt. (kg.)	Color Count	Color Count est. ug	Color Count ppb	AA Au (ug)	AA Au ppb	Precent Gravel	* Remarks
OCEANOGRAPHER CRUISE CONTINUED										
ANC 174	65°17.5'	167°43.2'	27.1				3.8	.1		
" 175	65°16.0'	167°23.7'	29.0				4.5	.2	<1	
" 176	65°15.9'	167°18.0'	11.0				1.4	.1	21	
" 177	65°16.6'	167°12.3'	11.0				2.4	.2	<5	
" 178	65°16.4'	167°02.3'	12.5				2.0	.2	<5	
" 180	65°~~16.2'~~ 13.4'	~~166°57.2'~~ 167°26.8'	11.8				7.8	.7	15	
" 181	65°13.0'	167°26.8'	12.5				1.6	.1	50	
" 182	65°10.6'	167°23.4'	11.1				1.4	.1	62	
" 183	65°09.5'	167°20.0'	14.6				7.0	.5	22	
" 184	65°08.2'	167°20.0'	19.9				12.0	.6	37	
" 185	65°05.4'	167°23.0'	25.3	few fine tr.	49.5	2.0	6.4	.3	19	
" 186	65°04.0'	167°22.0'	27.3	few fine tr.	49.5	1.8	1.8	.1	0	
" 187	65°02.1'	167°21.5'	30.6	very good tr.	300	9.8	9.3	0.3	12	
" 188	65°00.8'	167°19.5'	22.5	many fine tr.	66	2.9	3.4	.2	49	
" 189	64°59.0'	167°13.0'	36.8	1 fine tr.	16.5	0.5	25.6	.7	14	
" 190	64°58.0'	167°10.5'	17.3				1.5	.1	78	
" 191	64°54.0'	167°09.0'	7.9				1.5	.2	91	

Table 4 continued

Sample No.	Latitude	Longitude	Sample Wt. (kg.)	Color Count	Color Count est. ug	Color Count ppb	AA Au (ug)	AA Au ppb	Percent Gravel	* Remarks
OCEANOGRAPHER CRUISE CONTINUED										
ANC 193	64°50.5'	167°03.0'	20.1	few fine tr.	49.5	2.5	6.7	.3	21	
" 194	64°48.5'	166°58.5'	21.8				3.9	.2	27	
" 195	64°44.8'	166°53.7'	6.0	few fine tr.	49.5	8.3	0	0	15	
" 196	64°45.0'	166°50.5'	11.4				2.0	.2	16	
" 197	64°43.7'	166°47.2'	16.5				4.7	.3	15	
" 199	64°41.5'	166°39.2'	21.6				13.5	.6	57	
" 200	64°39.7'	166°36.5'	14.6				0	0	40	
" 201	64°38.5'	166°~~44.0'~~ 34.0'	11.7	three very good tr.	1000	85.5	162.7	13.9	71	
" 202	64°36.2'	166°31.2'	3.7	very good tr.	300	81.0	114.1	30.9	33	
" 203	64°35.7'	166°29.0'	23.8				65.0	2.7	33	
" 204	64°34.0'	166°26.0'	14.8				3.4	.2	8	
" 205	64°32.6'	166°23.2'	15.5	very good tr.	300	19.4	61.4	4.0	15	
" 206	64°31.2'	166°21.0'	20.4	many fine tr,	66	3.2	25.8	1.3	14	
" 210	64°33.6'	166°44.0'	19.2	many very good tr.	1300	67.7	307.6	32.8	56	
" 211	64°36.0'	167°0.7'	9.4	few fine tr.	49.5	5.3	6.9	.7	0	
" 213	64°40.3'	167°31.2'	10.4				1885.8	181.8		

Table 4 continued

Sample No.	Latitude	Longitude	Sample Wt. (kg)	Color Count	Color Count est. ug	Color Count ppb	AA Au (ug)	AA Au ppb	Percent Gravel	* Remarks
OCEANOGRAPHER CRUISE CONTINUED										
ANC 214	64°~~54.6'~~ 34.6'	167°44.0'	13.0				1.8	.1	7	
" 216	64°18.5'	168°20.8'	13.0				4.0	.3		
" 217	64°10.0'	168°40.4'	15.7				7.4	.5		
" 218	63°58.4'	168°30.4'	14.3				0	0		
" 219	63°47.95'	168°21.8'	15.2				10.1	.7		
" 220	63°56.13'	168°10.8'	29.4				2.2	.1		
" 221	64°03.8'	167°59.6'	28.1				3.2	.1		
" 222	64°09.5'	167°51.1'	16.9				1.9	.1		
" 223	64°17.31'	167°39.5'	12.1				2.8	.2		
" 224	64°18.29'	167°22.0'	8.3				2.0	.2		
" 225	64°19.83'	167°06.3'	17.4				3.9	.2	45	
" 226	64°20.4'	166°53.7'	16.9				1.9	.1	27	
" 227	64°22.7'	166°37.4'	10.7				2.1	.2	34	
" 228	64°23.76'	166°25.8'	15.1				0.9	.1	3	
" 229	64°18.4'	166°21.6'	21.7				1.8	.1		
" 230	64°13.9'	166°14.9'	21.0				2.0	.1		
" 231	64°20.8'	166°08.4'	25.5				3.4	.1		
" 232	64°25.4'	166°13.7	14.3				29.5	2.1	6.2	

Table 4 continued

Sample No.	Latitude	Longitude	Sample Wt. (kg.)	Color Count	Color Count est. ug	Color Count ppb	AA Au (ug)	AA Au ppb	Percent Gravel	* Remarks
OCEANOGRAPHER CRUISE CONTINUED										
ANC 233	64°26.5'	166°04.5'	22.7				3.4	.2	22	
" 234	64°29.9'	166°02.3'	19.7	2 good 3 fine tr.	109	5.5	164.9	8.4	39	
" 236	64°26.5'	165°48.0'	33.6	many fine tr.	66	1.7	61.2	1.8	15	
" 237	64°22.2'	165°51.0'	19.3				32.4	1.7	9.1	
" 238	64°15.4'	165°54.6'	9.0				1.5	.2	12	
" 239	64°11.0'	165°45.0'	24.4				0.4	< 0.05	4	
" 240	64°18.2'	165°40.2'	18.0				2.9	.2	2	
" 242	64°27.0'	165°35.9'	11.8	2 fine tr.	33	.1	33.4	3.3	15	
" 243										
" 245	64°24.0'	165°26.2'	40.8	9 good tr.	264	6.5	174	4.3	12	
" 246	64°19.6'	165°29.3'	21.7				29.8	1.4		
" 247	64°13.6'	165°31.2'	9.5				10.2	1.1		
" 248	64°10.2'	165°24.0'	2.6				3.2	1.2		
" 249	64°15.6'	165°16.0'	15.1				0	0		
" 250	64°20.8'	165°14.0'	36.0				6.0	.2	15	
" 251	64°25.0'	165°14.4'	20.2				16.2	.8	43	
"220-229 1/			9.8				99.5	10.0		
"231-245			5.7				71.6	13		

1/ Overpan sample is the material remaining after the pan concentrate has been removed. In this case overpan material from many samples of the same sediment type was combined and these composite sample groups were analyzed.

Table 4 continued

Sample No.	Latitude	Longitude	Sample Wt. (kg)	Color Count	Color Count est. ug	Color Count ppb	AA Au (ug)	AA Au ppb	Percent Gravel	* Remarks
TOMCOD CRUISE 1968										
AWF 378	64°29.3'	164°22.6'	18.1	2fine tr.	33.0	1.8	23.6	1.3	25	
" 379	64°29.8'	164° 20.5'	17.1	3fine tr.	49.5		76.0	4.4	15	
" 380	64°30.3'	164°18.5'	8.8				0	0	0	
" 381	64°30.3'	164°16.2'	9.9				.4	< 0.05	0	
" 382	64°30.2'	164°14.1'	3.9				9.9	1.7	0	
" 389	64°29.6'	163°57.0'	9.5				0	0	0	
" 390	64°29.7'	163°54.7'	10.4				0	0	0	
" 391	64°29.7'	163°52.5'	6.9				0	0	0	
" 392	64°29.7'	163°50.3'	7.4				0	0	0	
" 393	64°29.6'	163°48.0'	7.2				0	0	0	
" 394	64°29.7'	163°16.0	7.7				0	0	0	
" 395	64°29.6'	163°43.4'	4.9				0	0	0	
" 396	64°29.5'	163°41.0'	8.1				0	0	0	
" 397	64°28.6'	163°41.0'	10.7				0	0	0	
" 398	64°28.6'	163°43.4'	7.2				0	0	0	
" 399	64°28.7'	163°16.0'	8.6				0	0	0	
" 400	64°28.6'	163°48.0'	9.0				2.6	.3	0	
" 401	64°28.7'	163°50.3'	10.9				0	0	0	

Table 4 continued

Sample No.	Latitude	Longitude	Sample Wt. (kg.)	Color Count	Color Count est. ug	Color Count ppb	AA Au (ug)	AA Au ppb	Percent Gravel	* Remarks
TOMCOD CRUISE CONTINUED										
AWF 402	64°28.6'	163°52.5'	6.7				0	0	0	
" 403	64°28.6'	163°54.7'	11.1				0	0	0	
" 404	64°28.7'	163°57.0'	10.4				0	0	0	
" 405	64°29.8'	164°59.9'	10.9				6.0	.6		
" 406	64°29.2'	164°02.4'	9.1				11.8	1.3	44	
" 407	64°29.9'	164°04.8'	10.6				0	0	0	
" 408	64°30.0'	164°07.3'	10.4				3.6	.3	0	
" 409	64°30.1'	164°09.5'	9.3				0	0	0	
" 410	64°30.2'	164°11.8'	10.4	1 fine tr.	16.5	1.6	2.9	0.3	0	
" 411	64°19.3'	164°14.3'	5.6				0	0	0	
" 412	64°19.3'	164°16.4'	8.8				0	0	0	
" 413	64°29.4'	164°17.7'	21.1				0	0	10	
" 414	64°28.8'	164°19.5'	14.4	1 fine tr.	16.5	1.2	1.2	0.1	0	
" 416	64°28.1'	164°23.5'	17.3	2 fine tr.	33		11.0	.1	12	
" 417	64°28.8'	164°24.5'	13.0	1 fine tr.	16.5		9.6	.1	32	
" 430	64°28.4'	164°26.5'	17.4				1.8	.1	20	
" 431	64°28.0'	164°28.5'	16.9	two fine tr.	33.0	2.0	3.2	0.2	24	
" 432	64°27.5'	164°25.3'	6.9				1.6	.2	15	

Table 4 continued

Sample No.	Latitude	Longitude	Sample Wt. (kg.)	Color Count	Color Count est. ug	Color Count ppb	AA Au (ug)	AA Au ppb	Percent Gravel	* Remarks
TOMCOD CRUISE CONTINUED										
AWF 433	64°27.2'	164°27.5'	15.5				1.6	1.2	16	
" 434	64°26.6'	164°29.6'	16.3				0	0	12	
" 435	64°26.1'	164°36.6'	16.0				0	0	4	
" 436	64°25.6'	164°38.6'	16.0	2 fine tr.	33	2.1	4.8	0.3	30	
" 437	64°25.2'	164°40.5'	16.6				0	0	24	
" 438	64°24.6'	164°42.6'	15.8	1 fine tr.	16.5	1.0	2.8	0.2	17	1.2*
" 439	64°24.2'	164°44.5'	10.7				1.6	.1	48	
" 440	64°23.3'	164°46.5'	12.3				15.6	1.3	44	
" 442	64°23.3'	164°49.5'	11.4				15.2	1.3	55	
" 451	64°27.6'	164°25.5'	12.5					.1	17	
" 452	64°27.2'	164°27.3'	11.6					.1	26	
" 453	64°26.7'	164°29.2'	16.7	1 fine tr.	16.5	1.0	4.9	0.3	13	1.3*
" 454	64°26.3'	164°26.3'	16.0	2 fine tr.	33	2.1	12.8	.1	7	
" 456	64°25.3'	164°35.5'	34.7	1 fine tr.	16.5	0.5	7.3	0.2	12	
" 457	64°24.8'	164°37.4'	16.9				0	0	14	
" 458	64°24.3'	164°39.3'	20.2				4.4	.2	16	
" 459	64°23.8'	164°41.5'	9.5				5.8	.6	22	
" 460	64°23.3'	164°43.5'	13.9				0	0	39	

Table 4 continued

Sample No.	Latitude	Longitude	Sample Wt. (kg.)	Color Count	Color Count est. ug.	Color Count ppb	AA Au ug	AA Au ppb	Percent Gravel	* Remarks
TOMCOD CRUISE CONTINUED										
AWF 461	64° 22.8'	164°45.4'	19.6	2 fine tr,	33.0	1.7	4.2	0.2	22	
" 462	64°22.4'	164°47.2'	19.5	1 fine tr.	16.5		8.4	0.4	11	
" 463	64°22.3'	164°49.3'	19.7	2 fine tr.	33.0	1.7	7.4	0.4	18	
" 464	64°22.2'	164°51.5'	19.7				3.8	.2	23	
" 465	64°22.1'	164°53.8'	20.6	2 fine tr.	33.0	1.6	4.6	0.2	9	
" 466	64°21.9'	164°56.1'	21.8				0	0	13	
" 467	64°21.8'	164°58.3'	20.4				6.6	.3	22	
" 468	64°22.8'	164°58.5'	19.7					<0.05	5	
" 469	64°22.8'	164°56.2'	18.3				12.8	.7	29	
" 470	64°23.0'	164°54.0'	17.2				6.8	.4	30	
" 471	64°23.2'	164°51.8'	17.4	2 fine tr.	33	1.9	7.5	0.4	31	

metallic particles from a heavy mineral separate of the westernmost sample from the morainal area (ANC 93, Table 4) indicates that native copper is present (K. Venkatarathnum, mineralogist, Univ. Washington, written commun., 1968). Since AA analysis for gold destroys the sample, the nature of the colors in our pan concentrates from the St. Lawrence Island area cannot be confirmed, but we believe that they probably were native copper. To alluviate any problems from possible misidentification in these or any other samples, only AA and amalgamated gold weights have been used for average value and median value calculations except in the Pt. Clarence to Cape Prince of Wales region. (Table 3).

Gold distribution in fine sediments of open Bering Sea

The fine-grained sediments of open Bering Sea contain very fine visible, subvisible, and probably included gold particles; however, absolute gold contents of most samples generally have not been ascertained because panning, the main method of analysis, probably does not capture most of the subvisible gold nor included gold. Nevertheless, the values from concentration by panning should be statistically representative and are comparable over the area. Most samples seaward from the three mile limit in Chirikov Basin contain less than one ppb of particulate pannable gold (Table 4). Atomic absorption analysis of pan concentrates does confirm observation of visible fine traces of gold (<.250 mm) in sediments up to 20 miles (36km) from the nearest shoreline (see Table 3 samples ANC 81, 159, 161). One sample (ANC 213, Table 4) contained 182 ppb (.29/cubic yard) according to AA analysis, but this may be suspect because no visible gold was observed

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in the pan concentrates. The most reliable maximum values of particulate pannable gold near the center of Chirikov Basin seem to be those of about 10 ppb (see Table 4, sample ANC 165); near the three mile limit of open Bering Sea, appear to be those of up to 100 ppb (see Table 4, sample ANC 202).

One group of open Bering Sea samples (see Table 4, Thompson, TT-18, samples 13, 14, 17, 21, 24, 25, 29a, 29b, 31, 44a, 45) were elutriated to remove silt and clay sized particles of normal density, and the residue, which consisted of mineral particles of sand size and, perhaps some particles of heavy minerals of silt size, was subjected to AA analysis. All the residues, except one duplicate grab sample (see Table 4, sample TT-18, 29b) contained measureable amounts of fine visible and subvisible gold in about equal amounts; values ranged from 16-66 ppb of gold, or considerably more than that shown in most the 172 pan concentrate samples of open Bering Sea. The high values of the elutriated samples, may be explained in part, by the location of most of the samples less than 20 nautical miles from the shore where values generally are higher, and by better retention of very fine and subvisible gold than the panning method. However, values still appear to be anomalously high compared to values obtained from all other methods; this is especially true since analysis of whole sediment, which would have all of the included and subvisible gold of a sample, showed much lower values (see Table 4, Thompson TT-18, samples 11, 23, 44b, 47).

Atomic absorption analysis of size fractions of total sample material again results in values significantly higher than those obtained from pan concentrates, but less than those found in the elutriated concentrates even in duplicate samples (see Table 4, Thompson TT-18, samples 44a and 44b). The open Bering Sea samples (see Table 4, Thompson TT-18, samples 11, 23, 44b, 47) tested in this manner come from widely scattered locations greater than 20 miles (36 km) offshore, yet each sample value is very close to the overall group average of 10 ppb. An interesting corollary is found in about 20 Nome nearshore samples analyzed in the same way. Their overall average gold content was 10 ppb and individual sample deviation was very low; similar values and relationships were found for composited overpan[1]/ samples from open Bering Sea (sea Table 4 Oceanographer, last sample ANC 220-229 and 231-245).

1/Overpan sample is the material remaining after the pan concentrate has been removed. In this case part of the overpan material from many samples of the same sediment type was combined and these composite sample groups were analyzed in toto.

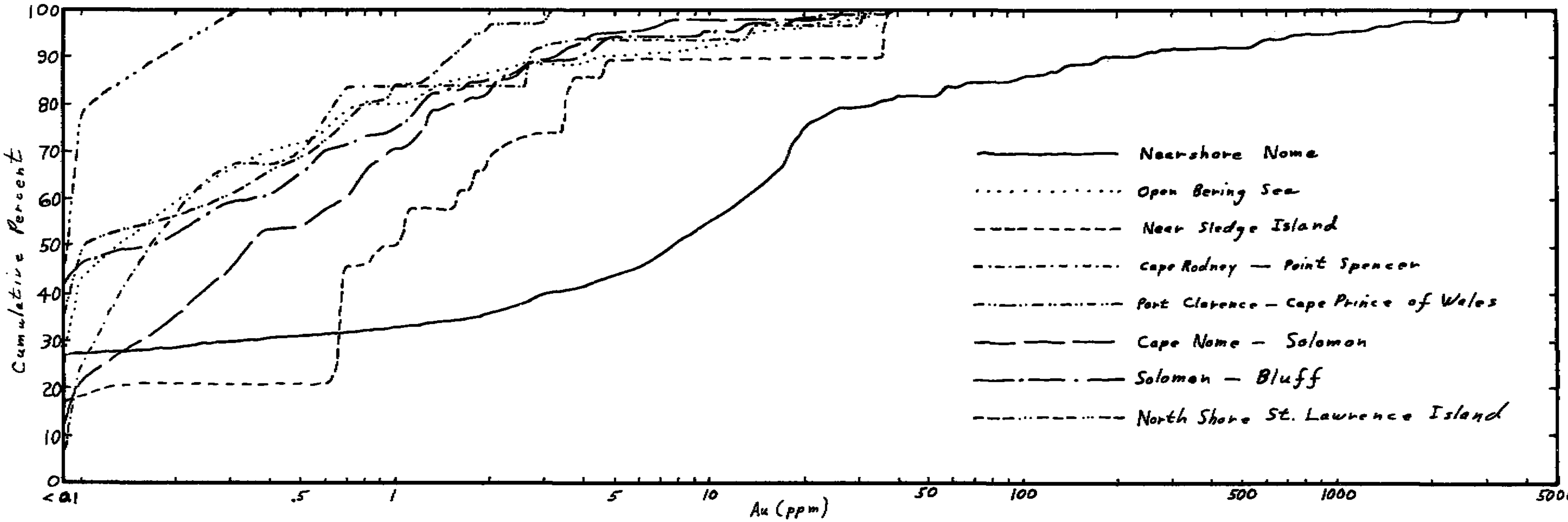
DISCUSSION

__Regional and Local Background values, gold size, and recognition of gold source regions__

Establishing absolute regional and local background values for gold is difficult because results vary with different analytical and preconcentration techniques, and because the particle sparsity effect may detract from the significance of value determinations for small samples with visible but very low gold content. The inconsistency of data that has been noted in the uniform silty sands of the open Bering Sea is an example of these problems. In the silty sand, samples weighing about 25 kg are required for statistically significant value determinations of gold content (Fig. 3, Clifton et al., 1969), because visible gold particles (ca. .250 mm to .1 mm) have been observed to cause a significant part of the value and because in most samples the tenor of particulate pannable gold is about one ppb or slightly less (Table 4). To meet these requirements, large samples of silty sand have been pre-concentrated by panning methods, since present techniques (Van Sickle and Larkin, 1968) make it impractical to analyze quantities of total sample material. As a result, only particulate pannable gold has been analyzed in most fractions and absolute gold content of whole samples has been ascertained in only a few widely spaced locations (see Table 4-Thompson Samples 11, 23, 44b, 47). The consistent determinations on the few analyses of whole sample material, as well as several other relationships, however, do suggest that absolute gold values of most open Bering Sea silty sands and also nearshore sediments without gold concentration is closer to 10 ppb than

to values a tenth as large indicated by pan concentrate samples. Analysis of whole sample material reveals that more than half of the gold content of sediment with no apparent gold concentration is in the subvisible range where small size generally prevents it from being retained in the gold pan. Also, most of the included gold of an sample would not be contained in a pan concentrate whereas it would in a total sample analysis. Generally higher content of visible gold in analyses of whole sample and of elutriated samples seem to suggest that some particulate pannable gold may be lost in the overwash. In addition, color count data seem to show that somewhere during the entire processing, and transfer of pan concentrates from the gold pan in the field to AA analyzer in the laboratory gold traces may be lost. A suggested background content of 10 ppb for these generally sandy sediments in an area of known sources (Chirikov Basin) agrees quite well with the most recent and reliable data of neutron activation determinations which gives an average gold content of 7.5 ppb for sandstone (Jones, 1969).

The absolute background values, although found to be about ten times greater than particulate pannable gold values in a few samples, have not been well defined locally or regionally, and may never by determined because of laborious analytical techniques required for samples of the size. Nevertheless, relative local and regional background values of particulate pannable gold have been established and do provide a common and regional basis for comparison. A convenient way to synthesize the data has been to plot the cumulative



Cumulative Frequency Distribution of Gold Values

Fig. #12

frequency percent of all particulate pannable gold values for each given region (Fig. 12). It is apparent that, except for the Sledge Island and Nome nearshore regions, about 75% of the values are less than one ppb; this suggests that the general background of particulate pannable gold in the bottom sediments of the Chirikov Basin is one ppb or less. An independent confirmation of this is the finding that in most pan concentrate samples with values greater than one ppb, visible gold was observed (Table 4). Since fine traced-sized gold apparently has been dispersed over most of the area, sparsely distributed sporadic occurrences of values above one ppb are not indicative of gold source regions. However, the occurrence of background values at the 75th percentile level of 20 ppb in the Nome region and of 3.5 ppb in the Sledge Island region (Fig. 12) represents a significant deviation from the regional background of pannable particulate gold observed elsewhere in Bering Sea and suggests the presence of nearby gold sources.

The regional median (or 50th percentile) values of pannable particulate gold vary from one part of the Chirikov Basin to another in a way that suggests a relationship to gold sources (Figure 12, Table 3, Column 4). All regional median values for nearshore areas along the coast of Seward Peninsula are greater than regional median values for the open Bering Sea or shoreline of St. Lawrence Island. This indicates that, except for the possible occurrences of coarse gold in the morainal areas north of western St. Lawrence Island, the major sources of gold in surface sediments are the present-day onshore or nearshore Seward Peninsula regions. The very low regional median values of samples from open Bering Sea and from the north coast of St. Lawrence Island imply that these are the areas that lie at the greatest distance from significant gold sources. Increasingly higher regional median gold values toward the Sledge Island and Nome nearshore regions, as well as

significantly higher regional median values within these regions suggests that these are specific source areas. Although the median gold values for most of the different environments within the Nome region are much greater than those in other regions of Chirikov Basin, the marked differences in median values from one to another of the local Nome nearshore sedimentary environments indicate a main gold source in relict gravels over till; median gold values of the Nome nearshore regions also suggest that the local background of pannable particulate gold, excluding this source area, is about 3 ppb.

Variation in the maximum size of gold particles found in the different regions seems to confirm the conclusions concerning source relationships based upon regional median values of pannable particulate gold (Table 3). Those regions far from the sources of pannable gold contain gold only up to fine trace size; the apparent source regions contain coarse gold particles of one mm or more in diameter while nearshore regions on the fringe of sources have gold up to medium sand size and relatively high quantities of fine trace-sized gold. Even in the local source region of Nome, the gold-size relationships are on a similar scale. The drift source areas contain gold in #2 or #3 colors (greater than one mm in diameter) while surrounding sediment has trace sized gold of medium sand size or less. The presence of coarse gold clearly identifies a source region, but it should be emphasized that lack of coarse gold does not eliminate the possibility that a given region may be the source of fine gold and that it may contain significant gold accumulations. Data on gold size from ancient beaches at Nome (A. E. Daily, written commun., 1968), and from the present beach there (Table 3) show that trace-sized gold can be carried and greatly concentrated on beaches. In this case,trends in background values are more significant than gold-size characteristics for the recognition of gold sources and areas of exceptional concentration. Since trace-sized gold is readily moved by long-shore drift, it is conceivable that significant gold accumulations away from sources may be found in beach areas where longshore drift has been obstructed. The concentrations of fine gold offshore from southern Oregon (Clifton, 1968) and northern California (Moore and Silver, 1968) may be examples of such a process.

Processes of Gold Transport and Dispersal

The distribution of gold particles of various sizes has important implications for sedimentary processes that disperse particulate gold offshore. The association of coarse gold (particles >1 mm in diameter) with drift and bedrock areas and the lack of it away from apparent drift and bedrock source regions suggest that in the marine environment only mass transport mechanisms have been able to move coarse gold for noticeable distances. The offshore drilling at Nome seems to show that small alluvial bodies in the high-value area of the drift do contain coarse gold; however, these ancient streams that crossed the drift when sea level was low apparently did not carry gold any great distance beyond the glacial source deposit. Lack of transport of coarse gold more than several miles in present land placer streams of the Arctic seem to substantiate this finding.

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All of our data points to the conclusion that most offshore gold has been scraped from bedrock and placer sources on land and carried to a point near its present position by glacial transport. Further, the association of coarse gold with glacial drift and the lack of coarse gold in offshore outwash fan deposits suggests that mass debris transport by glaciers has been most important in the transport of coarse gold. Apparently, outwash fan processes cover till sources and usually do not rework and carry significant amounts of coarse gold in the waning phases which deposited the outwash now found at the sea bottom. It is possible that early phases of outwash transport cutting through and reworking auriferous drift may concentrate and carry coarse gold offshore; limited evidence from drill holes off Nome appears to support this idea.

Ice-rafting is a transport mechanism that effects a limited redistribution of gold offshore at the present time. When pressure ridges of sea ice become grounded on auriferous sediments, coarse gold can be plucked up and then carried further offshore until melting causes it to be dropped back to the sea floor. Since our data on gravel distribution indicate that ice-rafting has only a limited effectiveness in redistributing coarse terrigenous debris a similar case can be inferred for coarse gold transport. Relict gravel areas are commonly surrounded by an aureole of pebbly mud, approximately represented by the regions delineated on figure 10 where the bottom sediments contain 1 to 10% gravel. Coarse gold is not likely to be rafted beyond this aureole, and indeed, we found almost no coarse or

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medium sized gold beyond the aureole of pebbly mud. The single exception is an occurrence of medium-coarse gold, probably ice-rafted, in recent mud offshore from the beach at Bluff, which is a source of coarse gold.

Shoreline processes have been extremely important for concentrating coarse gold in source regions as well as for transporting trace-sized gold away from sources. Surf-zone erosion and selective transport, removing the finer sediment, appear to have been the key factors in concentrating gold in relict gravels over the drift and bedrock areas. Several transgressions and regressions of the shoreline took place as a consequence of Quaternary eustatic changes in sea level. Gold bearing drift and auriferous bedrock were extremely reworked and significant concentrations of gold in the relict gravels were formed at the sea bottom. Since all of the Chirikov Basin is shallow (Fig. 1) the entire sea floor has been subjected to longshore drift processes at one time or another during the Holocene transgression. We believe that the trace-size gold particles found in the fine bottom sediments were dispersed by longshore drift during the progression of the shoreline across the basin. Modern currents of about 15-25 cm/sec (Fig. 1, Fleming and Heggarty, 1966) appear to be swift enough to prevent sediment deposition in most offshore parts of the basin, but they are not strong enough (Hjulstrom, 1938; Sundborg, 1956) to move trace-size gold particles, which have an effective diameter of about .4 mm (R. Martin, U.S. Geological Survey, unpublished data) from the nearshore sources; yet, gold particles of this size are found far

offshore throughout much of the basin (Fig. 11). The nearshore distribution of trace-sized gold and of median gold values (Table 3) also suggests that longshore transport has moved fine gold laterally along ancient and modern shorelines and that fine gold has not been moved perpendicularly away from the shore. The recently deposited mud south from Nome and east of Solomon lack trace-sized gold, while the relict sediments immediately east and west of the Nome region commonly have trace-sized gold in sediments and have higher median values. The great abundance of trace-size gold in the modern beach, in submerged beaches, and in ancient beaches on land again suggests that longshore drift transport is most important in the ~~transport~~ movement of fine gold.

Offshore bottom currents have played their principal role in preventing deposition in the areas of gold concentration, but the strong bottom currents in the Nome nearshore region may have dispersed small amounts of trace-sized gold. The effective density curves of Martin (unpub. data) and size velocity curves of Sundborg (1956) suggest that fine traces of gold (ca.<.5 mm) can be moved by the strongest nearshore currents (75-100 cm/sec) known in the Nome region (Fig. 1); indeed, the recently deposited sediments off Nome which surround drift source areas do have trace-size gold. However, the distribution pattern of gold and data on bottom currents indicate that modern bottom currents can not transport gold far beyond the Nome nearshore region nor can they move medium and coarse gold from the source regions, even in nearshore areas.

SUMMARY AND CONCLUSIONS

Samples from 51 drill holes and about 700 surface sediment locations in northern Bering Sea show that gold is widely dispersed on the floor of the Chirikov Basin, northern Bering Sea. In the richest area near Nome, the bottom sediments have an average gold content of nearly 1,000 ppb and the predominant size of gold flakes is one mm in diameter; however, in most areas 75 percent of the samples contain one ppb or less of pannable particulate gold flakes ranging from about .25 mm to subvisible size. Because the richer areas contain coarser gold, the particle sparsity effect must be considered in gold poor as well as gold-rich areas. Our data indicates that about 25 kg (55 pounds) of sample are required in order to obtain a reliable estimate of the gold content of any type of sediment from northern Bering Sea. For samples of this weight, one may conclude with 95% confidence that the true gold content of the particular sedimentary environment that has been sampled, differs by no more than ±50% from the gold content of the sample itself (Clifton et al., 1969). To analyze such large sample quantities, even on shipboard, we suggest screening out the gravel fraction, which can then be studied for roundness and lithology to determine sedimentary environment; next elutriation can be used to remove silt and clay, and then the residue can be panned. Inadequate sample size, as in the case of our Nome nearshore samples, can be compensated for by calculating moving averages in homogeneous sedimentary environments. Comparison with statistical probability curves, generated for samples with low and

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varible weights, suggests that the average values are representative and that coarse gold can be randomly distributed within restricted areas of certain sedimentary environments. This statistical analysis provides a basis for preliminary evaluation of the economic potential for rich areas of homogeneous sediment.

Over the total northern Bering Sea region distribution of gold values is not random, but is correlated specifically with sedimentary environments and location. The richest concentrations and coarsest particles (one mm or larger) of gold occur in relict gravels that mantle glacial drift lobes in the Nome nearshore region or in gravel patches over bedrock in the Sledge Island area. These bodies of relict gravel which are characterized by predominance of gravel and lack of silt and clay formed during transgression and regression of the shoreline when eustatic changes of sea level occurred in Pleistocene times. Relict gravels over outwash fans appear to have no concentrations of gold in their upper surface and contain only fine-size particulate gold. However, drilling suggests that local outwash channels buried in glacial drift and alluvial channels cut into the surface of the glacial drift can contain significant concentrations of gold. The submerged beach gravels, which are identified by their bathymetric location, and pebble roundness and lithology, contain coarse gold; although concentrations of gold in surface samples are significantly lower than those of relict gravels over drift, the gold content may be greater in the buried back beach deposits. Except along the present shoreline, Holocene sands and muds throughout most of northern

Bering Sea usually contain just occasional fine-sized gold flakes (.25 mm or less in diameter) and have no concentration of particulate gold. The total amount of gold in sediments with no gold concentration appears to be about 10 ppb, with half or more of the gold content contributed by subvisible and included gold. Because gold panning does not not retain subvisible and included gold and because few whole sediment samples have been analyzed, total background gold content of Chirikov Basin sediment is not well established and cannot be used for comparitive relations. Nevertheless, the restricted gold content of pan concentrates can be used to establish a relative and comparable background of pannable particulate gold. When median values of the cumulative frequency distribution of pannable particulate gold values of local regions are compared, gold source regions and distribution processes can be characterized. Trends toward higher median values of pannable particulate gold and slightly coarser gold in the bottom mud near the Seward Peninsula coast point to the Nome-Sledge Island area as a major source for the gold dispersed in the finer sediments of northern Bering Sea. Local source regions can be identified not only by the gradiation to larger median values in local regions surrounding them but also by median gold values of local source areas that are about 10 times or more than those of normal local regions (ca. .2 ppb or less) and by gold particles of one mm or greater in diameter that remain in the source region.

Lack of movement of gold particles one mm or more in diameter indicates that coarse gold is not transported beyond the source regions

by normal marine processes. Either bedrock sources of gold must be present offshore, or mass transport mechanisms of glaciers must have carried the coarse gold offshore; although, modern-day ice rafting, in rare instances, seems to have dropped coarse gold into offshore fine sized sediments that lack gold but contain rafted pebbles. Fine gold apparently can be widely dispersed from source regions by marine processes. Theoretically, the strong currents known to exist in the nearshore regions should be able to carry the fine gold. However, sediments recently deposited from currents generally lack visible gold; and, relict sediments, [redacted] apparently laid down by Holocene transgression of the shoreline across the Bering Sea, often contain fine, visible gold. This suggests that longshore drift is mainly responsible for dispersal of fine gold particles throughout surface sediments of northern Bering Sea. Absence of gold concentration, but presence of fine, visible gold in nearly half the samples of relict gravels east of the Nome region, where eastward longshore drift has predominated, again confirms the idea that longshore drift is mainly responsible for dispersal of fine gold.

The main conclusion that can be drawn from the gold distribution relationships is that, as in the land placers at Nome, shoreline processes have been most critical for gold concentration and dispersal in Chirikov Basin. The modern currents also have been important for they apparently prevent recent sediment deposition over much of northern Bering Sea, and consequently, relict auriferous sediments laid down by the last shoreline transgression remain exposed at the sea bottom. In the limited locations where old depressions, particularly stream valleys, have been filling with recent current-deposited sediment, little visible gold is found. Where the wave processes of the shoreline transgression have reworked auriferous till, very rich concentrations of coarse gold have remained in the thin layer of relict gravels on the surface of the sea bottom.

It appears that a potentially mineable deposit is present in the mantle of relict gravels over drift off Nome, and that other prospects merit detailed sampling as possible additional gold resources. Statistical analysis for the richest six square mile area of the highly auriferous relict gravels indicates that coarse gold distribution is random, that samples are representative, and that the gravel averages 920 ppb in gold. Particles of a millimeter or more in diameter are mainly responsible for gold tenor in the relict gravels over glacial debris, however this may not be the case for the submerged beach ridges. Trace-sized gold (.3 mm or less) accounts for values greater than 10,000 ppb in ruby sands of the modern beach and often is the size mode of ancient emergent beaches that were mined on land. Although coarse gold and high background values suggest that there are gold concentrations in submerged beach sediments, only relatively low gold values were encountered. These low values may be misleading because buried locations, such as at the base of the back beach where the concentrations would be expected, have not been sampled. Very closely spaced drilling and vertical sampling increments would be necessary to detect such deposits, which

are most likely to occur where inner beaches have been cut into auriferous till. The coarse gold and high background values in gravel patches over seafloor bedrock of the Sledge Island region indicate a possible offshore bedrock gold source; this area as well as the gravel shoal to the northwest are other promising areas for gold exploration. In addition, confirmation of the presence and possible economic potential of coarse gold and (or) native copper in morainal gravels off St. Lawrence Island is recommended.

In regions of relict sediments, it is apparent that gold content of surface samples can identify and outline placer accumulations of gold in surface and underlying materials. However, where there is a cover of recently deposited fine-sized or muddy sediment which generally lacks gold values, underlying deposits may be masked. The recent muddy sediments of the nearshore region off Bluff usually lack gold, yet presence of coarse gold has been confirmed in a buried offshore channel. Buried placers also may be present off the mouth of the Solomon River, but samples of the surficial relict gravels there are very discouraging. Most of the central part of Chirikov Basin is not an encouraging place for further prospecting, because the bottom sediments are fine grained and bedrock that might furnish local sources of gold lies buried beneath many hundreds of feet of Cenozoic sediments. Although subvisible gold adds significantly to background values [redacted] of normal sediments of northern Bering Sea, and it is more abundant in rich samples, very low total content of subvisible gold does not justify its consideration as a mineable resource.

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